CSG-Stump: A Learning Friendly CSG-Like Representation for Interpretable Shape Parsing

– Supplementary Materials –

A. Signed-Distance-Field Calculation

To compute the signed distance of a point x with respect to a primitive p, we first transform the point x from the world coordinate system into x' in primitive's local coordinate system as discussed in Sec.4.2 of the paper.

Box We define the origin of a box's local coordinate system as the box center. Its shape is defined by a 3 dimensional positive vector $Q_{Box} = \langle Q_{Box}[0], Q_{Box}[1], Q_{Box}[2] \rangle$ indicating the box's width, height and depth. Since our defined boxes are symmetric about the coordinate system's x–y x–z and y–z planes, we can transform the point x' to the first octant by $|x'| = \langle |x'_x|, |x'_y|, |x'_z| \rangle$ without changing its signed distance. We also define utility functions $f_{max}(\vec{x}, a) = \langle \max(x_0, a), \max(x_1, a), \max(x_2, a) \rangle$ and $g_{max}(\vec{x}, a) = \max(x_0, x_1, x_2, a)$ to ease our discussion.
Thus we can compute the Signed-Distance Field of a box $SDF_{\square}$ as follows:

$$SDF_{\square}(x') = ||f_{max}(|x'| - 0.5 \cdot Q_{box}, 0)||_2 + \min(g_{max}(|x'| - 0.5 \cdot Q_{box}), 0) \tag{1}$$

Note that the first term is in charge of computing SDF when a point is outside of the box, and the second term for inside points.

Sphere Similarly, we define the origin of a sphere's local coordinate system as the sphere center. The shape of a sphere is defined by a positive scalar Q_{sphere} indicating its radius. Thus the Signed-Distance-Field of a sphere $SDF_{\bigcirc}$ can be defined as follows:

$$SDF_{\bigcirc}(x') = ||x'||_2 - Q_{sphere} \tag{2}$$

Cylinder We define the z-axis of a cylinder's local coordinate system as the cylinder's axis. The shape of a infinitely long cylinder is defined by a positive scalar $Q_{cylinder}$ indicating its radius. Thus the Signed-Distance-Field of a cylinder $SDF_{\bigsqcup}$ can be defined as follows:

$$SDF_{\bigsqcup}(x') = ||x'_{x,y}||_2 - Q_{cylinder} \tag{3}$$

Cone We define the origin of a cone's local coordinate system as a cone's apex, and the cone is extending downwards along the z-axes. The shape of a cone extends infinitely far is defined by a positive scalar Q_{cone} indicating its opening angle. Thus the Signed-Distance-Field of a cone $SDF_{\triangle}$ can be defined as follows:

$$SDF_{\triangle}(x') = \begin{cases} ||x'||_2 & \text{if } x'_z \geq 0 \\ \frac{(||x'_{x,y}||_2 - x'_z \cdot \tan(Q_{cone}))}{\sqrt{1+\tan^2(Q_{cone})}} & \text{otherwise} \end{cases} \tag{4}$$

B. Toy Dataset

Apart from the two shapes shown in Fig.3 of the paper, the rest of the toy dataset is shown in Fig.A, which consists of multiple complex shapes defined using a multilevel CSG-Parse-Tree with different boolean operations and different types of primitives.

C. A Complete CSG-Stump Example (16 $\times$ 16)

We show a raw output of CSG-Stump Net in Fig.B. We plot the complete CSG-Stump with estimated primitives and connection matrices for an airplane shape trained with 16 primitives and 16 intersection nodes.

D. Visual Results

We show more generated results in detail in Fig.C. Note that all meshes are parametric shapes exported using openSCAD. We also include a video showing the generated shapes in 360 degree views.

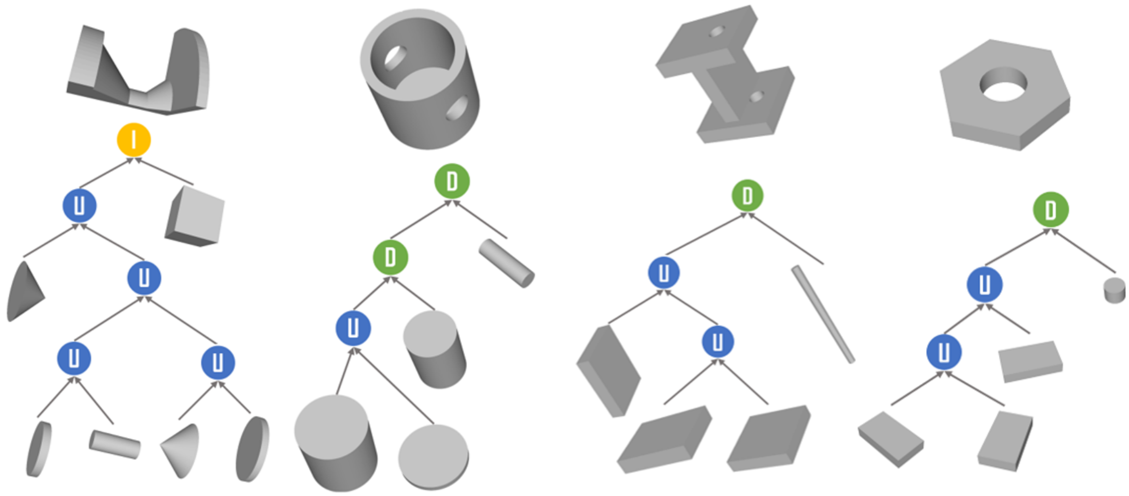

Figure A. The toy dataset for CSG-Stump Optimization.

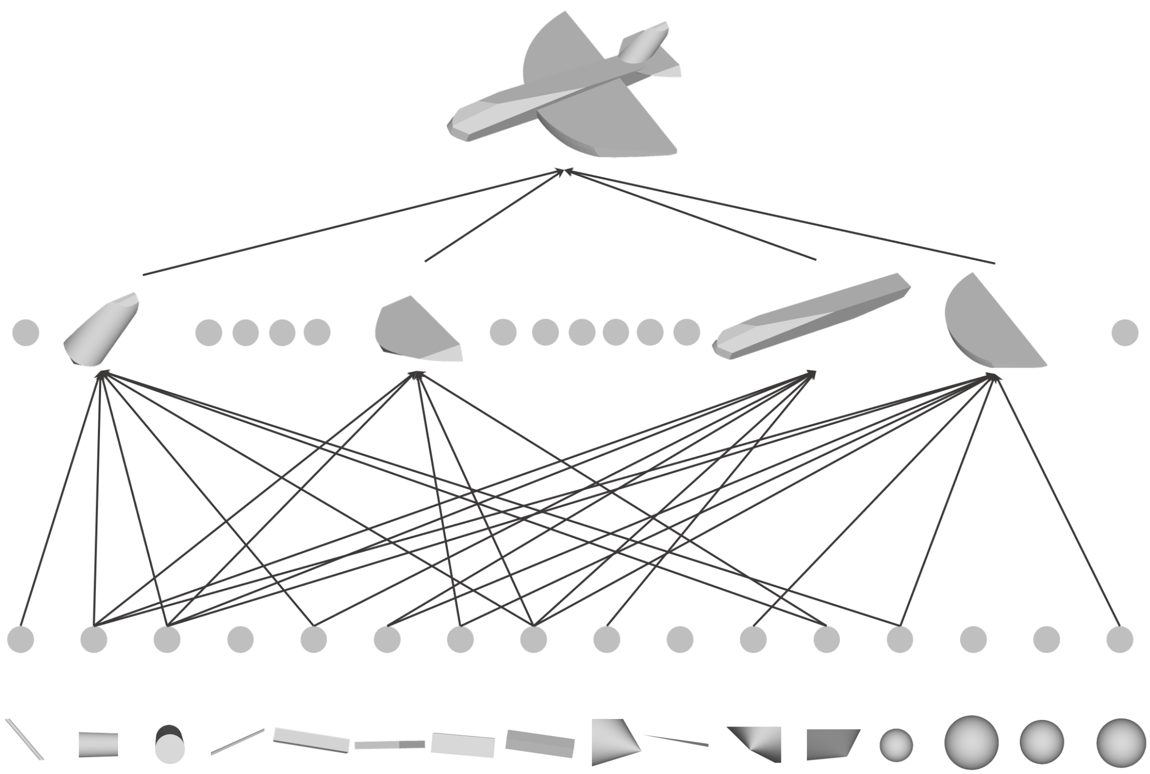

Figure B. Our predicted CSG-Stump structure with 16 primitives. Note that this CSG-Stump is directly outputted from our model without any modification and simplification.

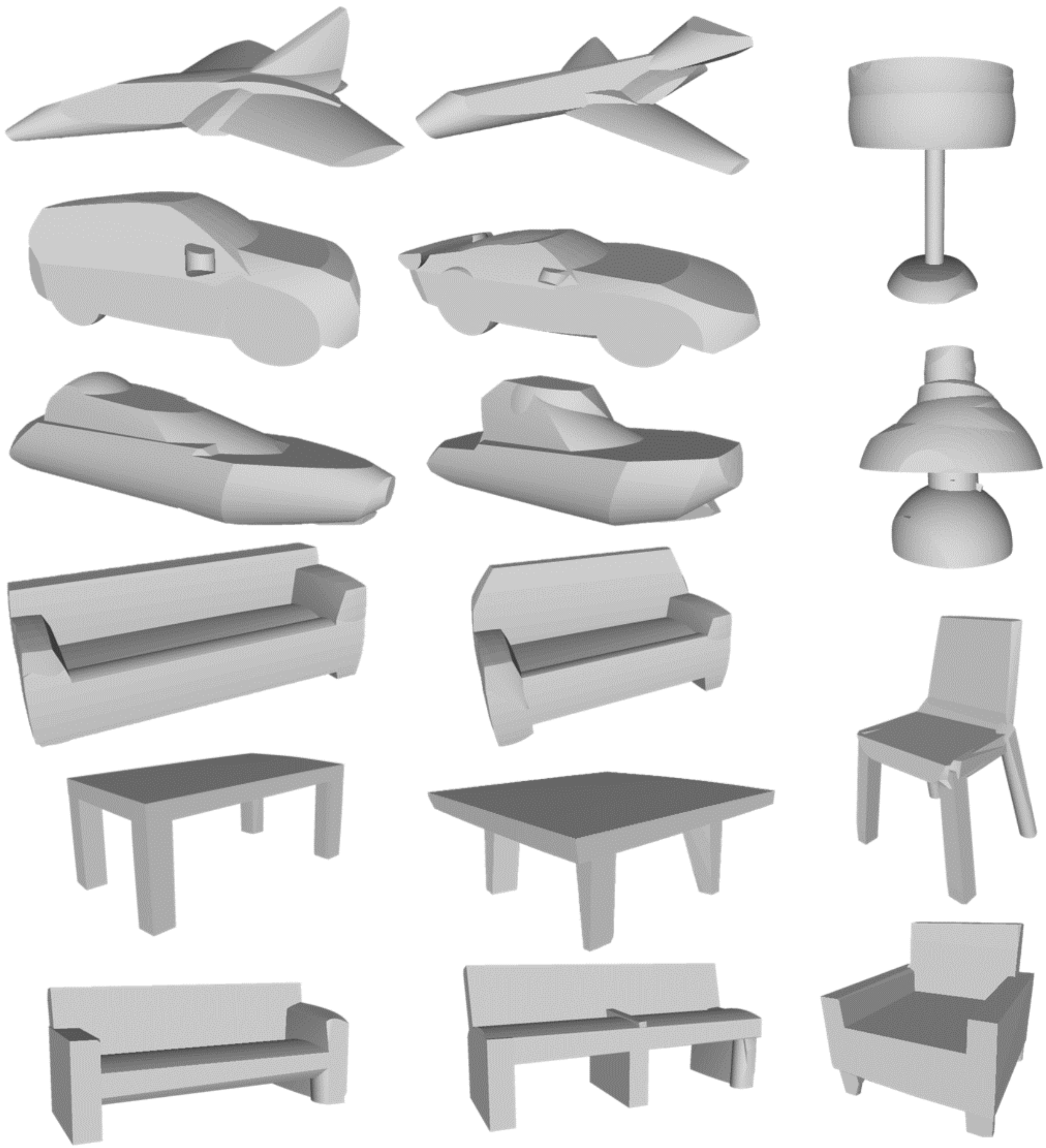

Figure C. Our generated shapes rendered by CAD Software.