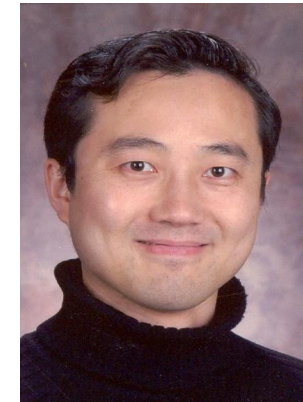




D²CSG: Unsupervised Learning of Compact CSG Trees with Dual Complements and Dropouts

Fenggen Yu¹ Qimin Chen¹ Maham Tanveer¹ Ali Mahdavi Amiri¹ Hao Zhang¹

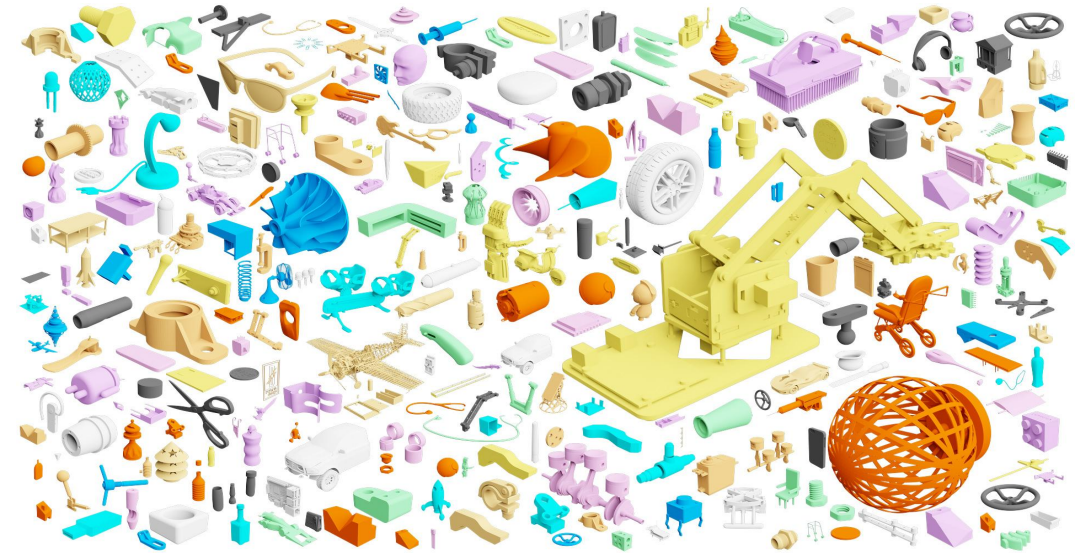
¹Simon Fraser University



3D CAD Models



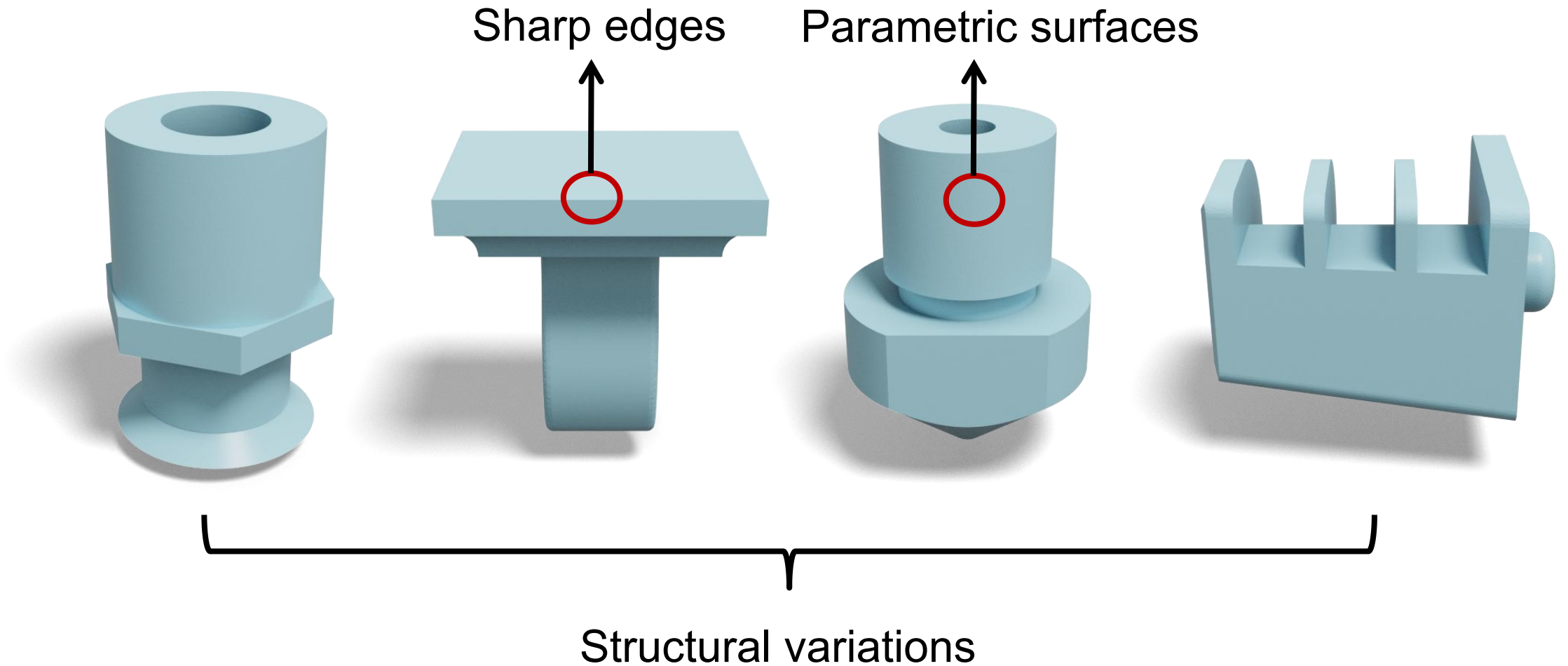
ABC Dataset, Koch et al CVPR 2019



Fusion 360 Gallery, Karl et al TOG 2021

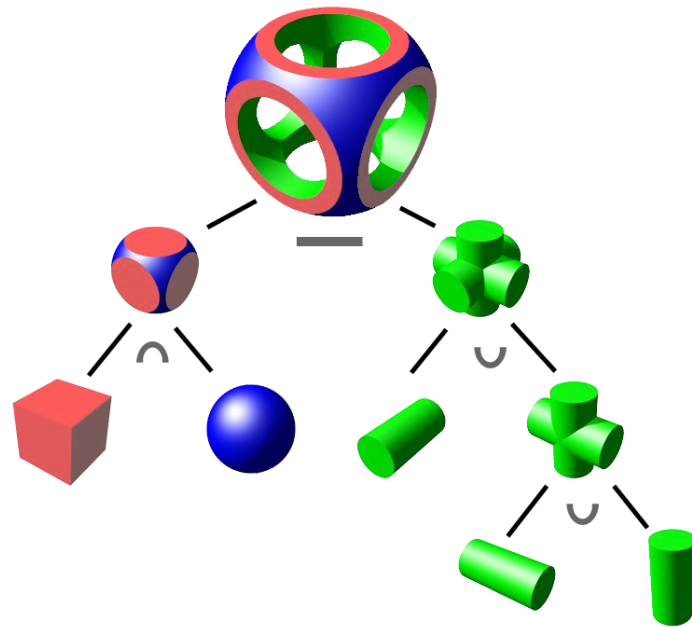
Computer-Aided-Design (CAD) models are widely used in industry design

Learning CAD Model Reconstruction

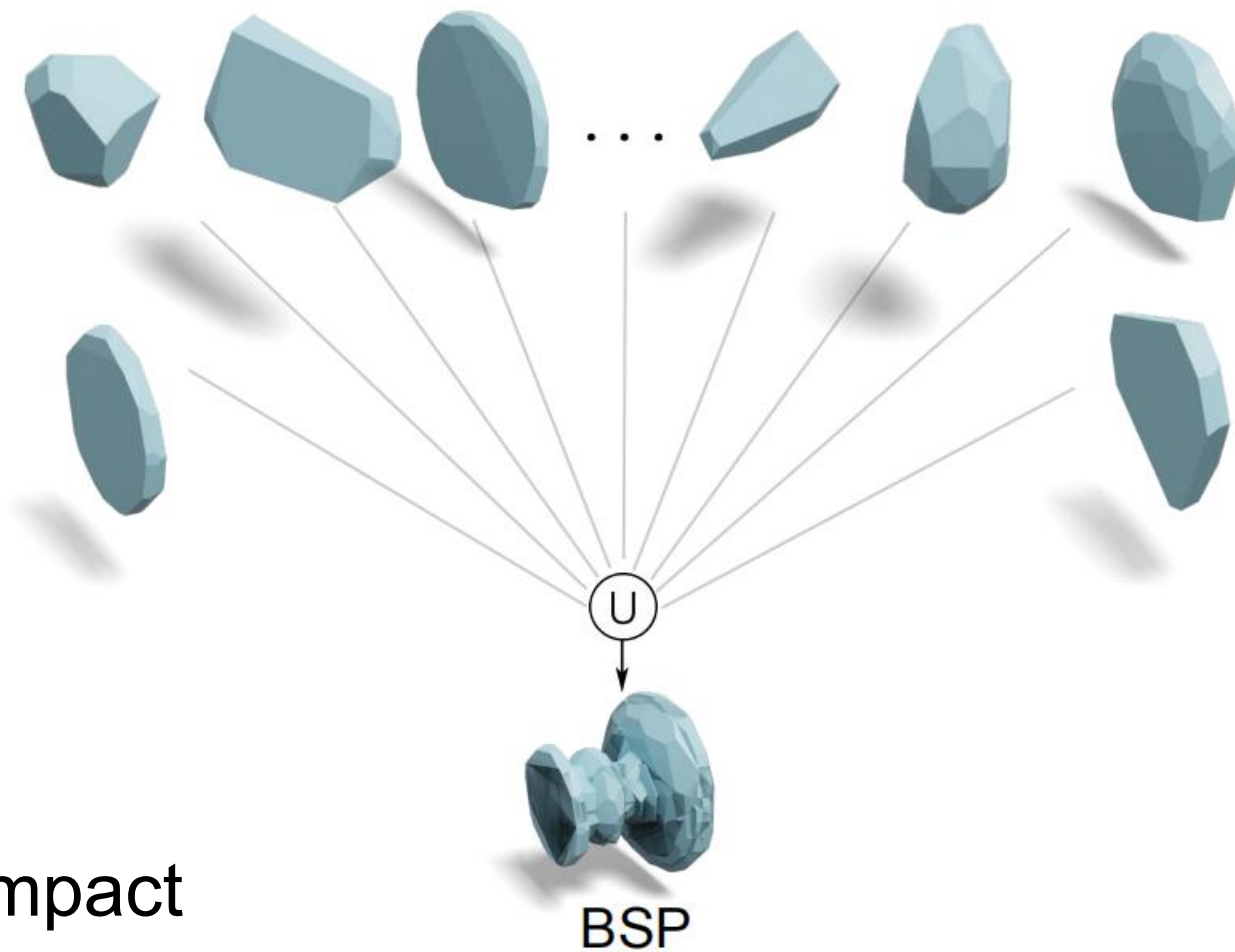


CSG-based CAD Modeling

- Constructive Solid Geometry(CSG) operations are popular in CAD modeling
- **Goal:** Unsupervised learning the CSG sequence for a given 3D shape

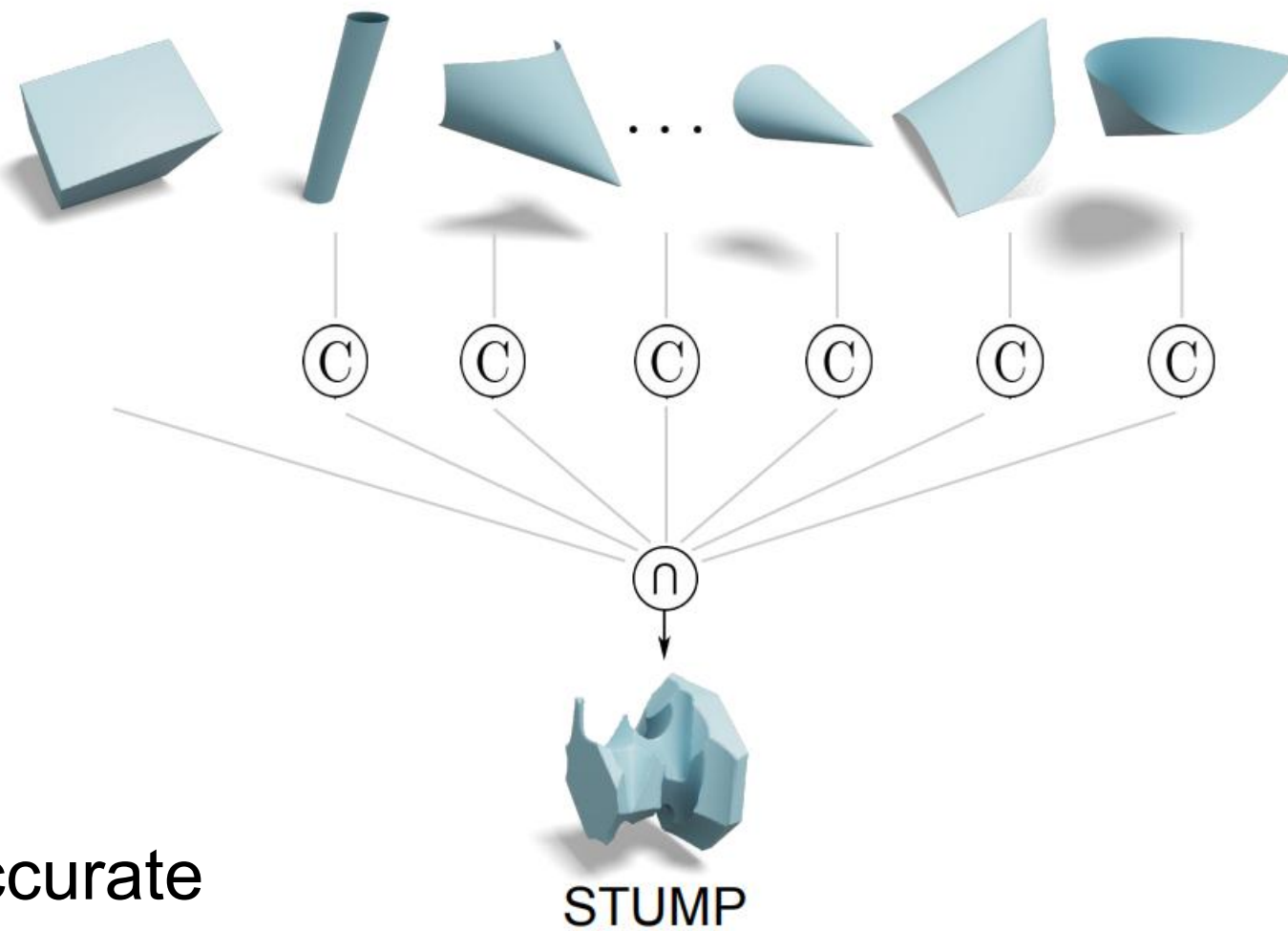


Learning CSG



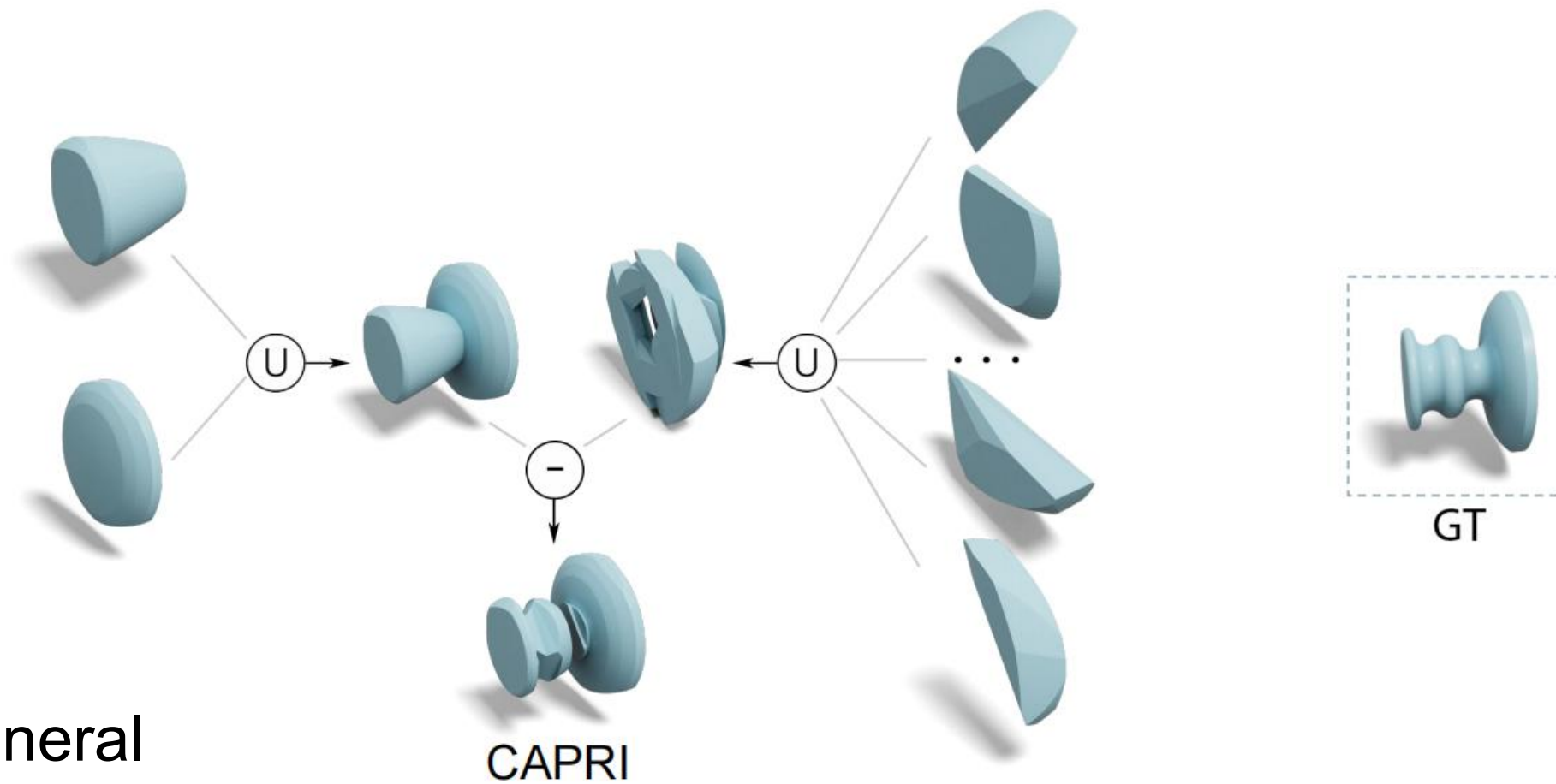
☹ Not compact

Learning CSG

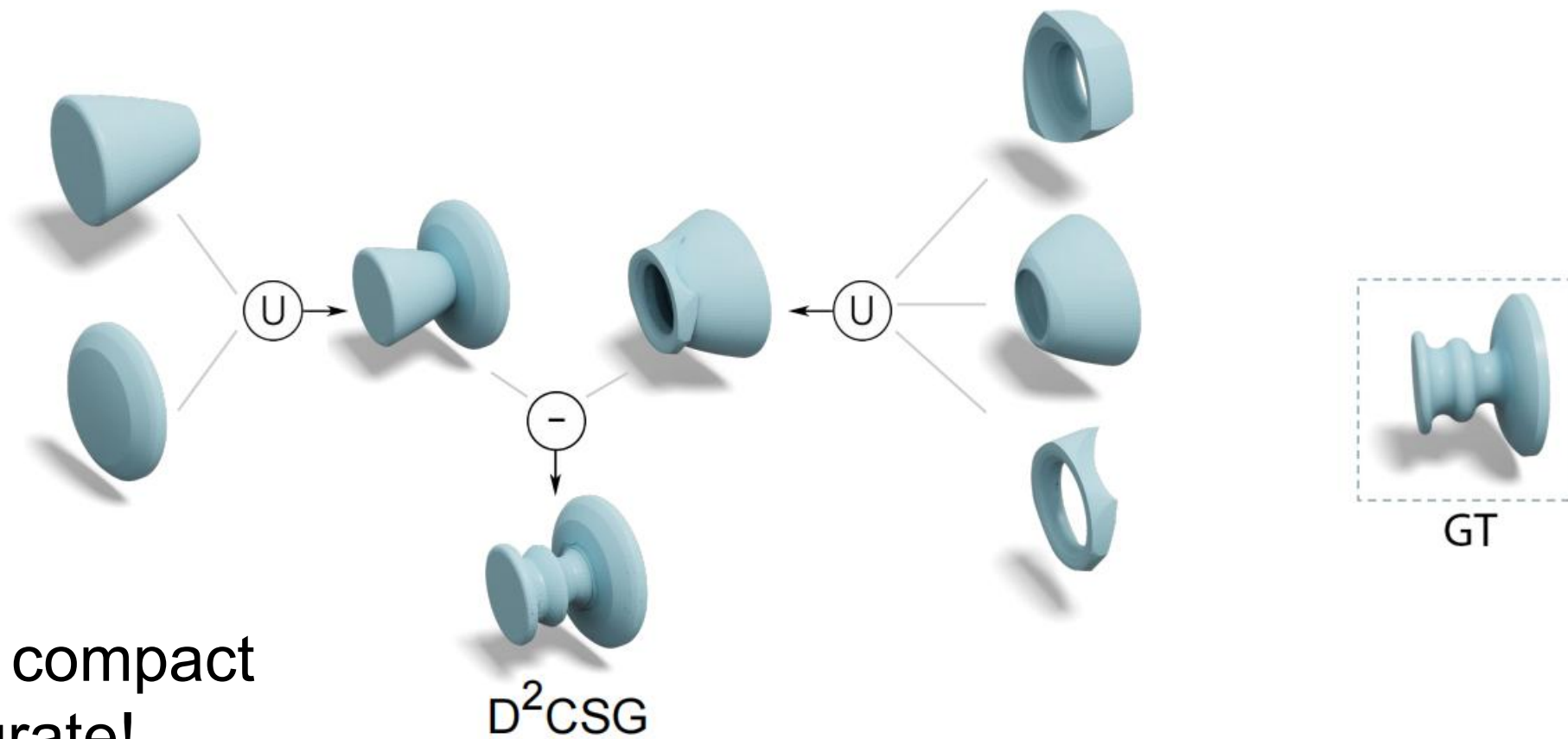


☹ Not accurate

Learning CSG

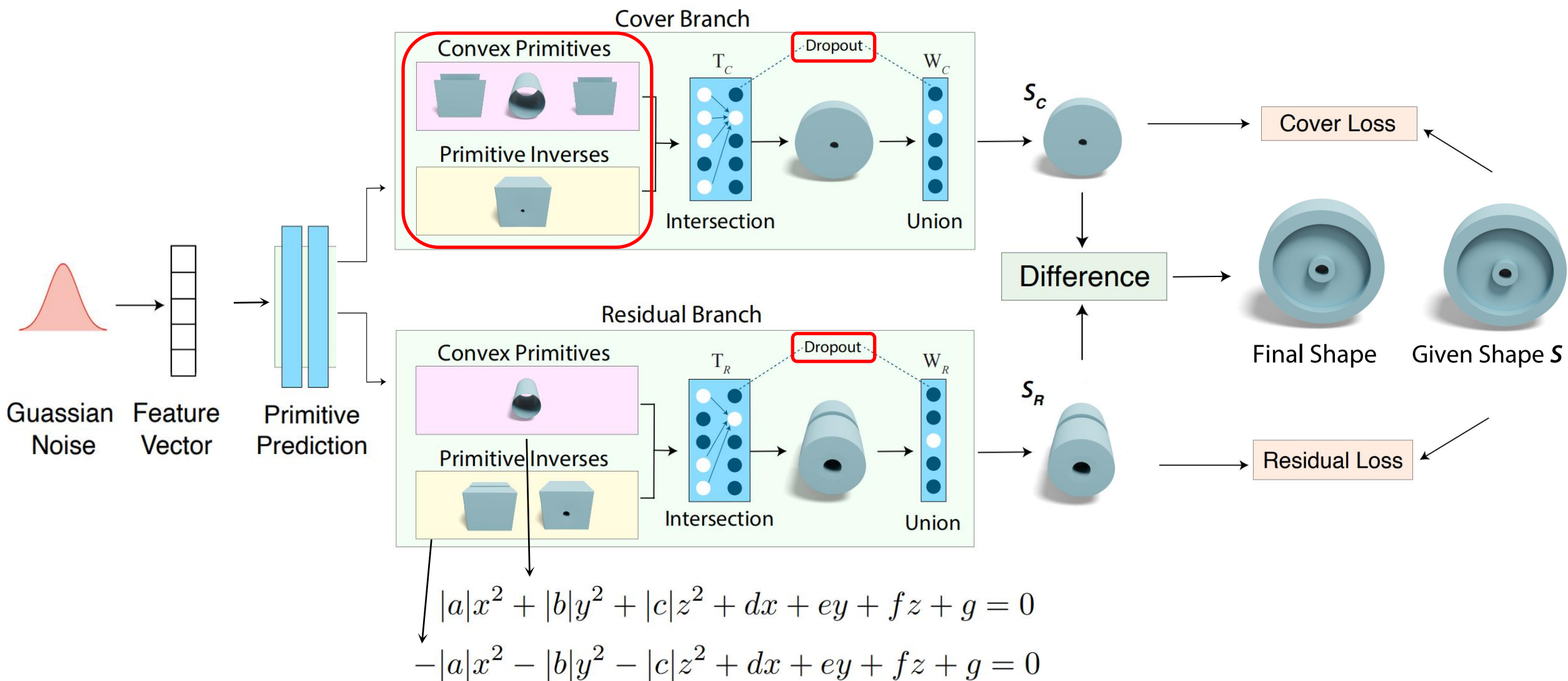


Learning CSG

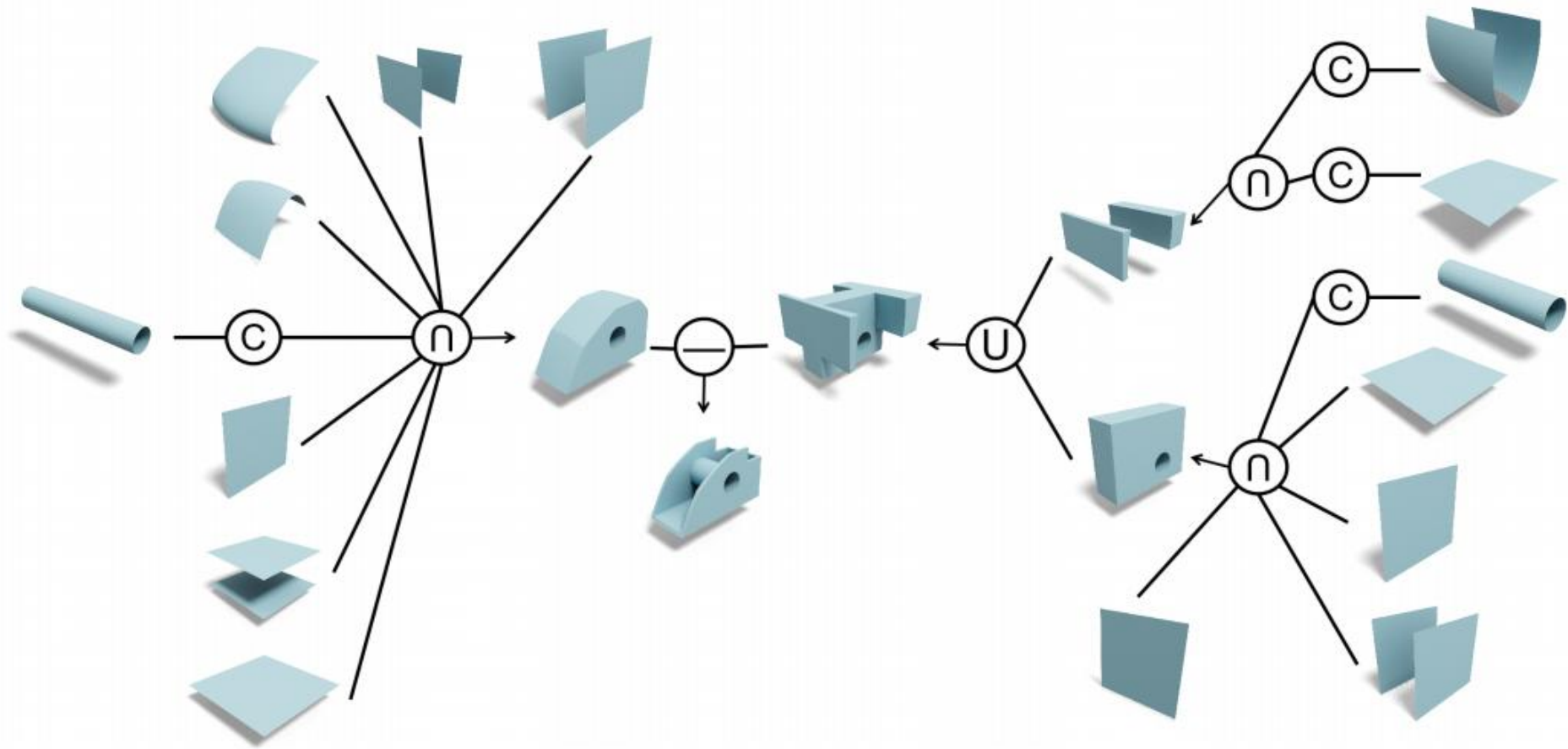


General, compact
and accurate!

Network Overview



Learned CSG Tree



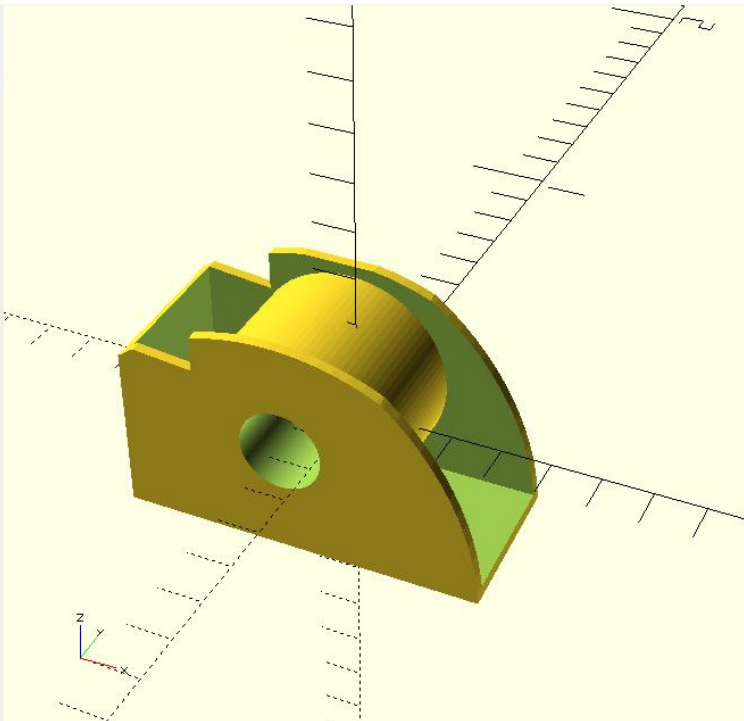
Editable CSG Program

final.scad - OpenSCAD

File Edit Design View Window Help

Editor

```
1 difference() {
2   union() {
3     intersection() {
4       translate(v=[5.585416688192037e-23,
5         0.13377228362093085, -9.121677682219595e-07]) {
6         rotate(a=-90.00286331324241, v=[-
7           0.0070690696895147, -0.007069069689514646,
8           0.9999500270050746]) {
9             cube(size=[0.6236710691612392,
10              0.9843750000000001, 0.9932846971966294],
11              center=true);
12           };
13         };
14       translate(v=[8.37535195561743e-05, -
15         0.0005411572363230984, 0.5229710797586785]) {
16         rotate(a=0.05999406284615443, v=[
17           0.9882344674910861, 0.15294651765440573, -0.0
18         ]){
19           cube(size=[1.5, 1.5, 1.5],
20           center=true);
21         };
22       translate(v=[-0.2401465465611436, -
23         0.0062602054453046, -0.25633765640869965]) {
24         rotate(a=90.06402828574511, v=[-
25         0.9993560752549403, -0.03588084239593828, 0.0
26         ]){
27           cylinder(h=1.0093404174735627,
28             r=0.5673262359054215, center=true, $fn=100);
29         };
30       };
31       translate(v=[4.891320821222938e-19, -
32         4.891320821222938e-19, -0.007988133108465995]) {
33         rotate(a=180.0, v=[
34           0.7071067811865475, 0.0, -0.7071067811865475]) {
35           cube(size=[0.48106121729162915
36             , 0.9843749999999999, 0.984375], center=true);
```



Console

(at your option) any later version.

Loaded design 'D:/workspace/DualCSG/dualcsg/Reconstructions_test_csg_primi_all_3/00053584_stage_3/final.scad'.

Compiling design (CSG Tree generation)...

Compiling design (CSG Products generation)...

Geometries in cache: 12

Geometry cache size in bytes: 64032

CGAL Polyhedrons in cache: 0

CGAL cache size in bytes: 0

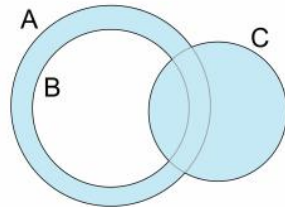
Compiling design (CSG Products normalization)...

Normalized tree has 264 elements!

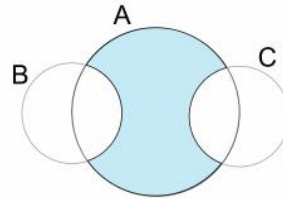
Group	File
-------	------

Generalization Proof

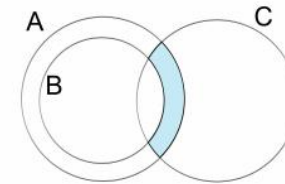
- The operation sequence in D²CSG is able to support any CSG sequence



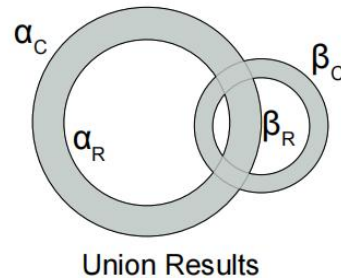
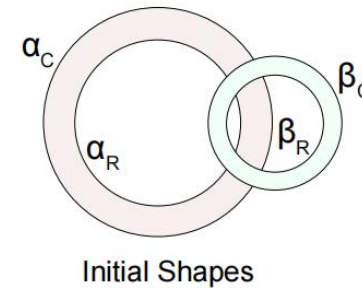
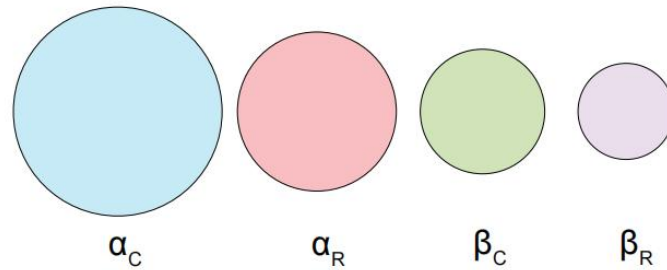
Rule 1: $(A - B) \cup C = (A \cup C) - (B - C)$



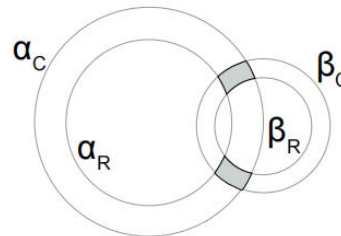
Rule 2: $A - B - C = A - (B \cup C)$



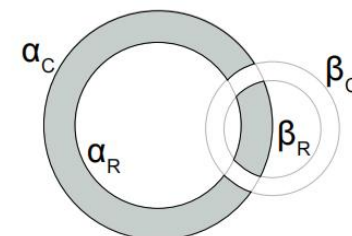
Rule 3: $(A - B) \cap C = (A \cap C) - (B \cap C)$



Union Results

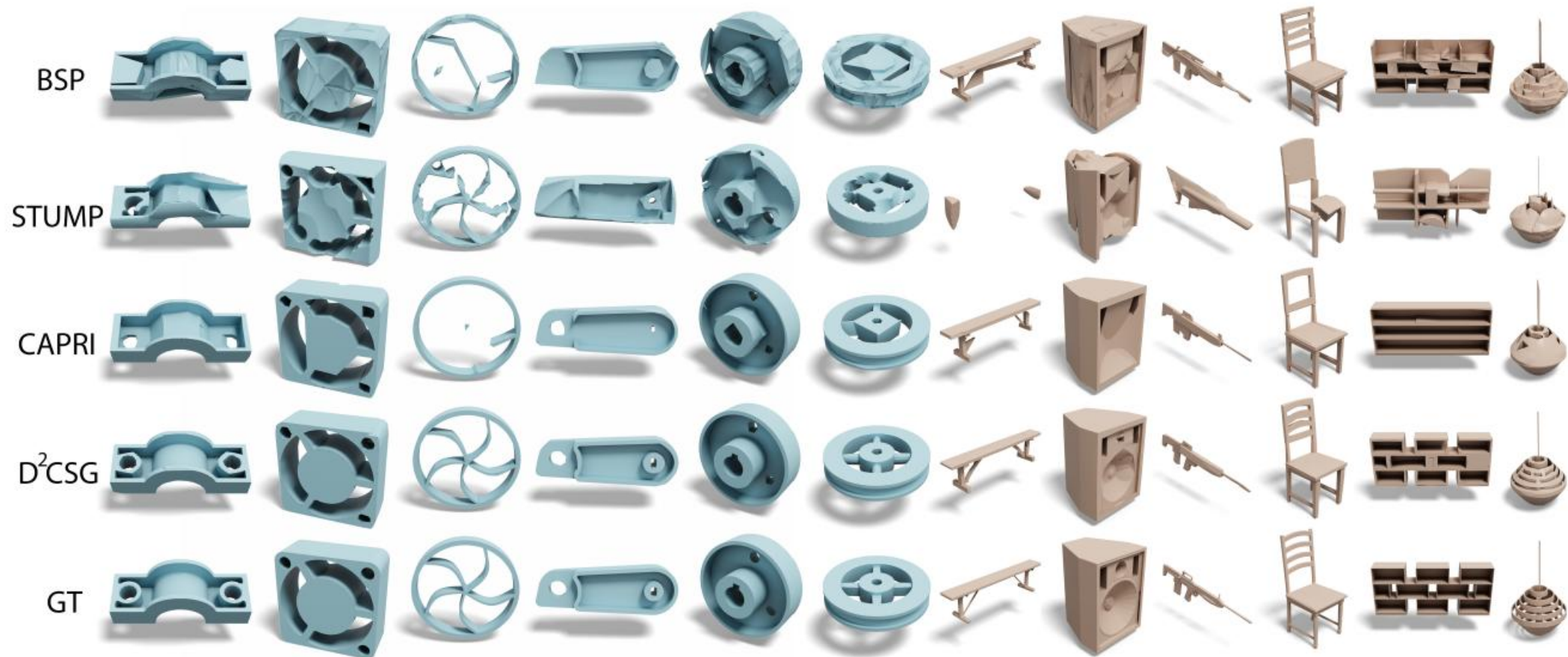


Intersection Results



Difference Results

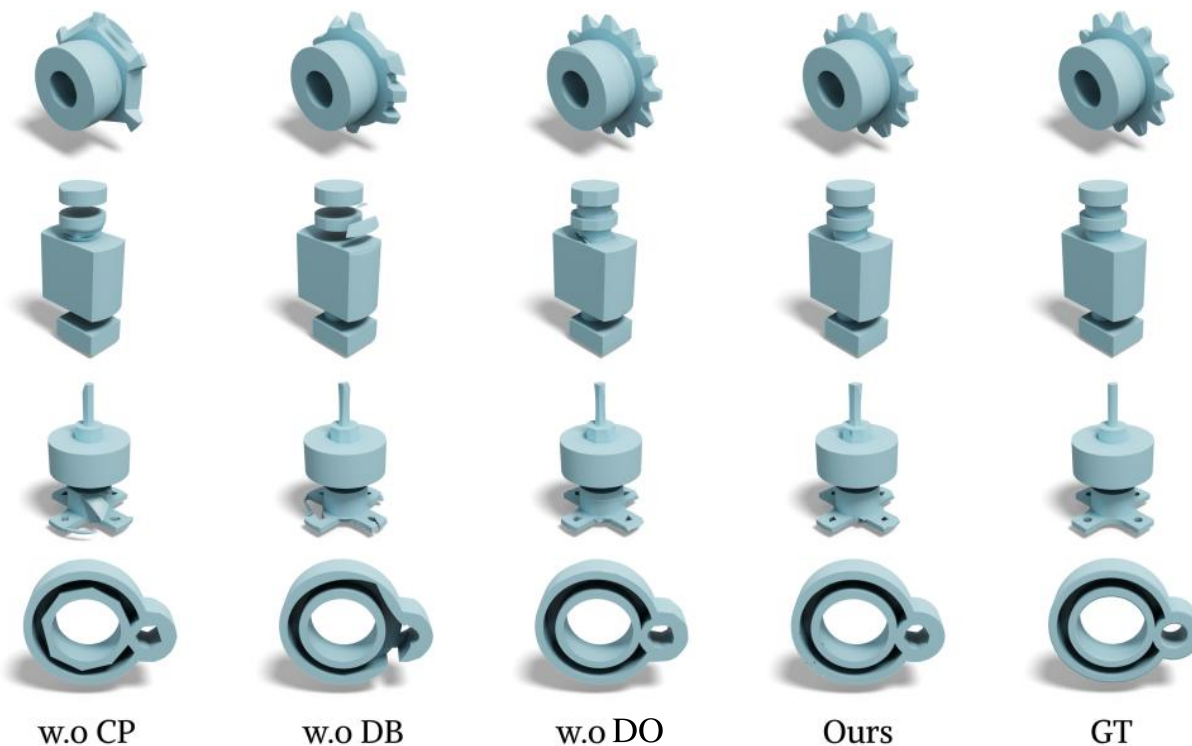
Experiments: Mesh-to-CSG



ABC DataSet

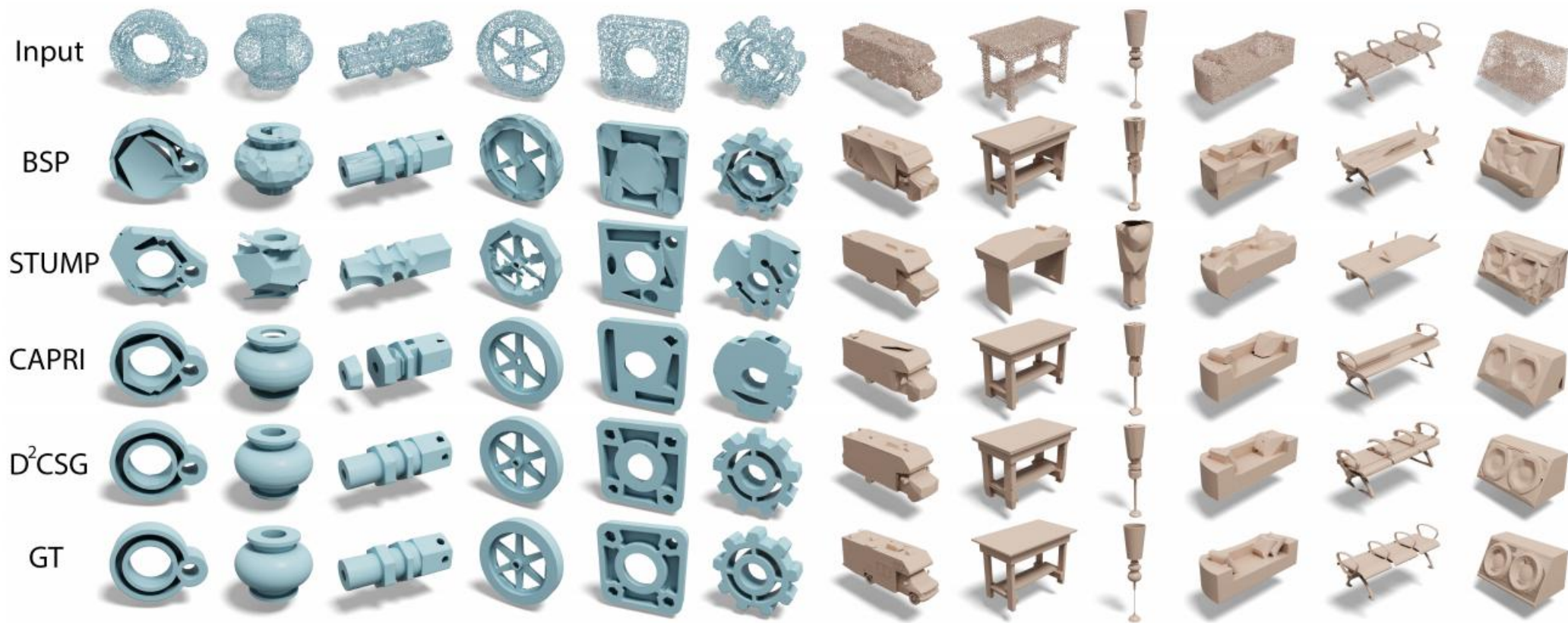
ShapeNet

Experiments: Ablation Studies



Row ID	CP	DB	DO	CD ↓	NC ↑	ECD ↓	#P ↓	#IS ↓	#Seg ↓
1	-	-	-	0.183	0.907	3.92	77	9.2	93
2	✓	-	-	0.073	0.935	3.12	38	5.8	55
3	✓	-	✓	0.088	0.926	3.48	27	5.3	40
4	✓	✓	-	0.069	0.936	2.98	53	6.8	57
5	✓	✓	✓	0.069	0.928	3.09	29	5.7	42

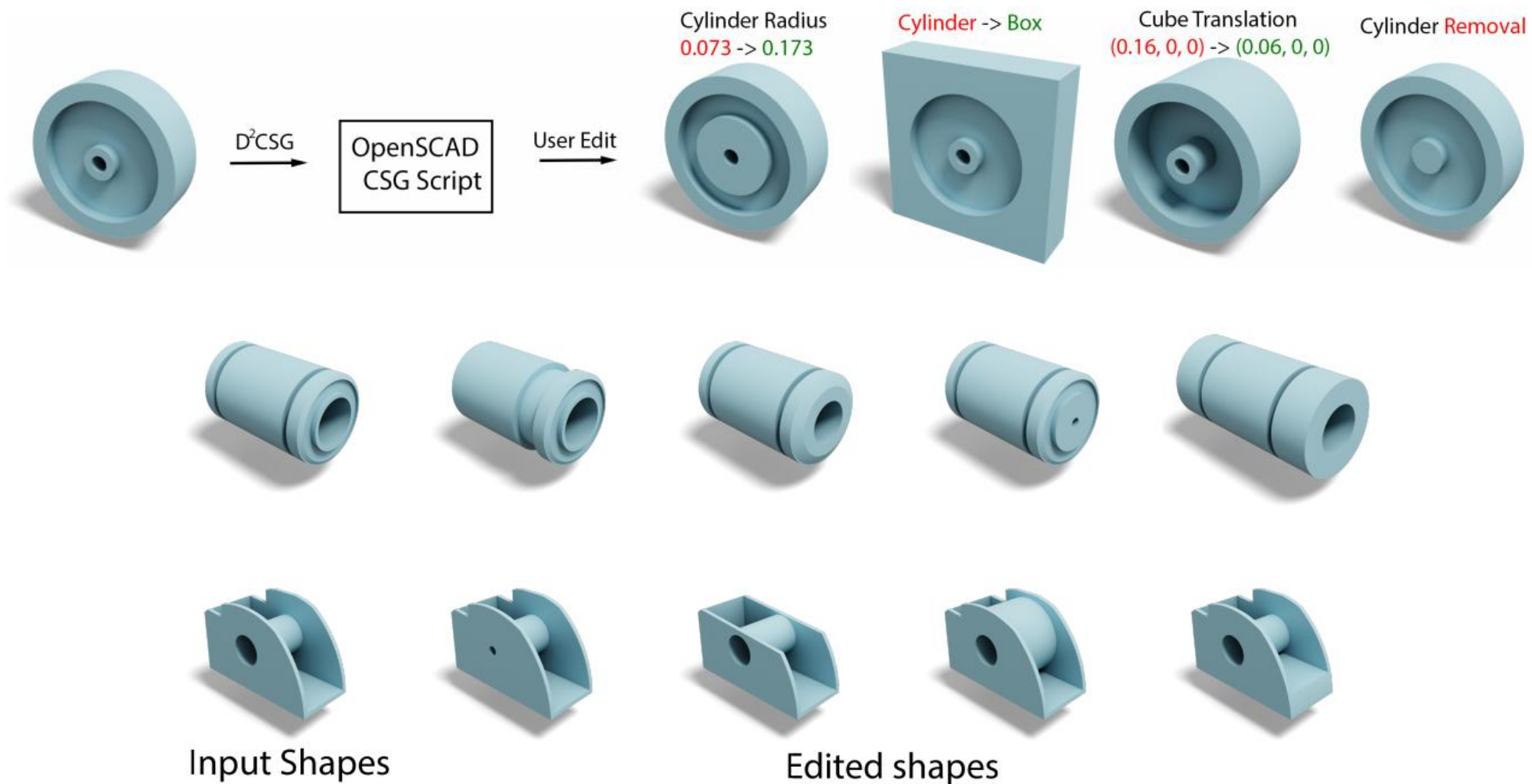
Application: PointCloud-to-CSG



ABC Data Set

ShapeNet

Application: Shape Editing



Thank you!