Parametric 3D CAD with OpenSCAD

or... Drawing 3D objects with code

Graham Klyne, @gklyne

Install and start OpenSCAD

- Web site:
  - http://www.openscad.org/
- Manual:
  - http://en/wikibooks.org/wiki/OpenSCAD_User_Manual

Key features

- Parametric
  - Users of objects define dimensions and features
  - A single design can be realized for different uses
  - Designs can be adjusted to use available materials
- Coding not drawing
  - Algorithmic specification of complex shapes
    - e.g. teeth on a gear
  - Errors can be corrected by changing the code
  - Build new designs on shared materials
  - Not necessarily for everyone

Viewport survival guide

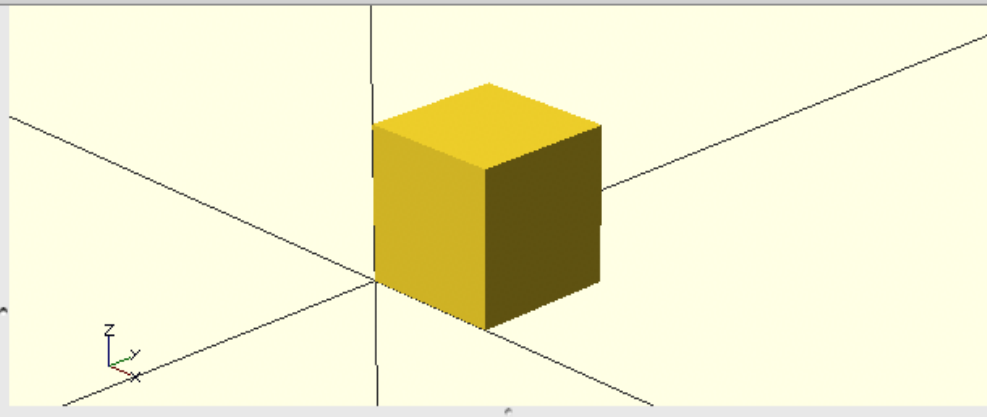
- Quick display update: F5
- Full recompute and display update: F6
- View > Show axes: COMMAND/2
- Pan view:
  - Right-drag
- Zoom view:
  - Scroll-wheel, or “+”, “-”
- Change text size:
  - COMMAND/“+”, COMMAND/“-”

Primitive solid shapes

- Cube / cuboid
- Cylinder/cone
- Sphere
- *Also, general polyhedron and extruded -D shapes are possible, but I won't go into that.*

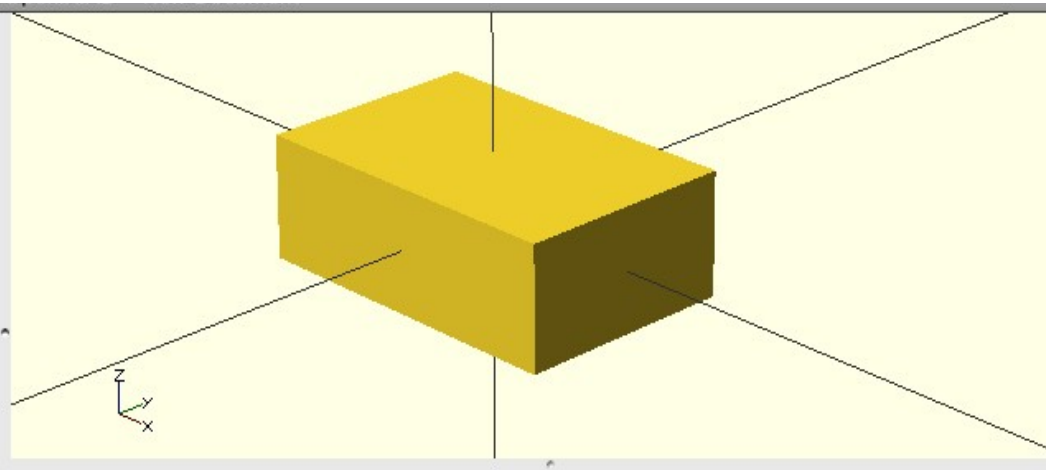
Cube / cuboid

```
cube(size = 1);
```



```
Parsing design (AST generation)...
Compiling design (CSG Tree generation)...
Compilation finished.
Rendering Polygon Mesh using CGAL...
Number of vertices currently in CGAL cache: 40
Number of objects currently in CGAL cache: 4
  Top level object is a 3D object:
```

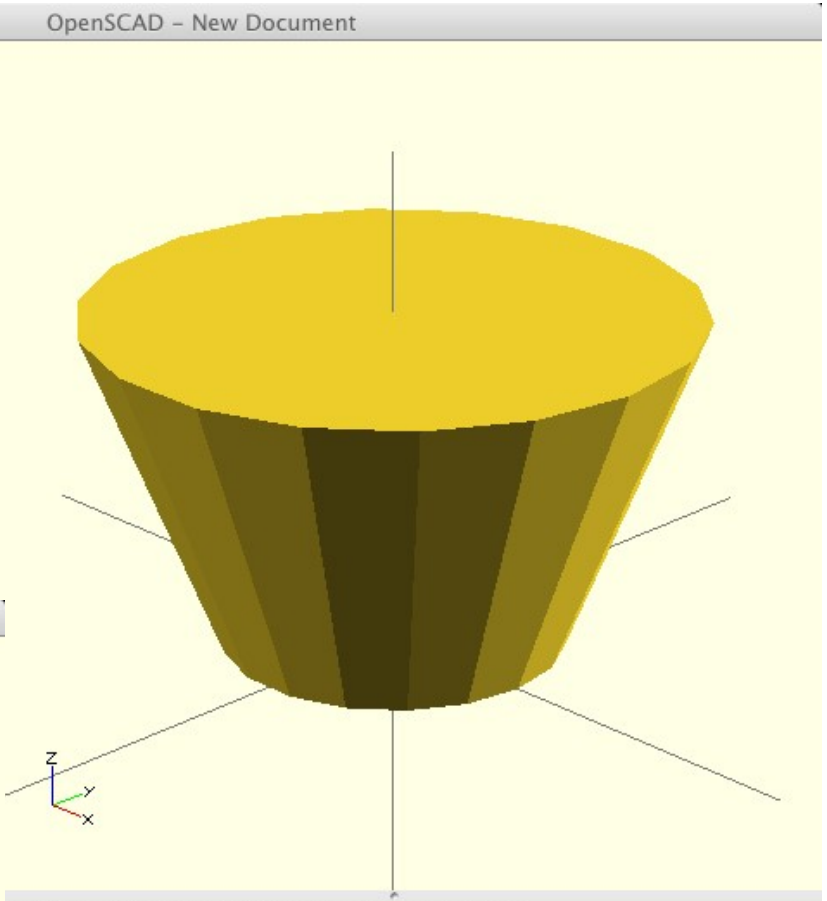
```
cube(size = [3,2,1],
     center = true);
```



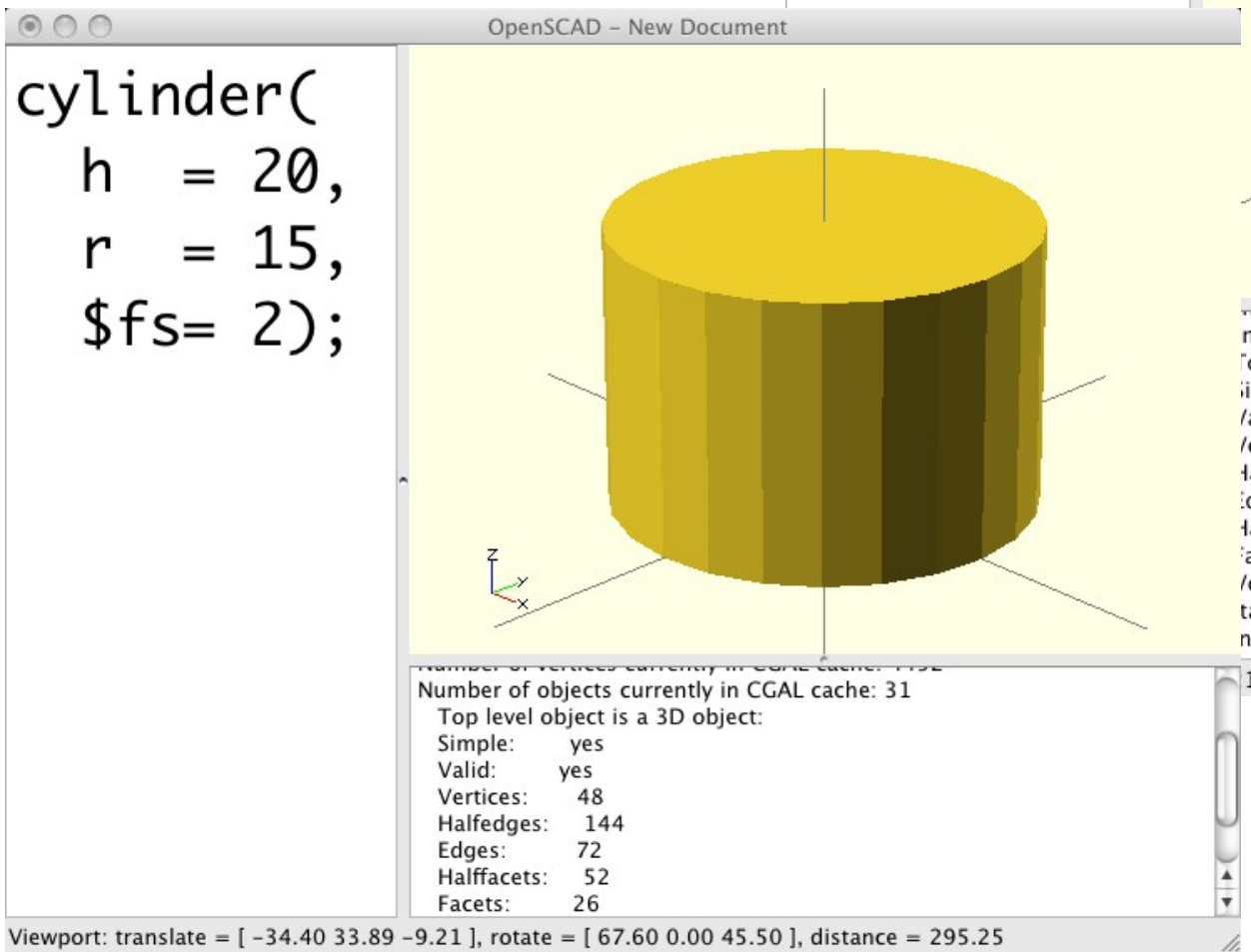
```
Halfedges:    24
Edges:        12
Halffacets:   12
Facets:        6
Volumes:       2
```

Cylinder and cone

```
cylinder(
  h  = 20,
  r1 = 10,
  r2 = 18,
  $fa= 20);
```



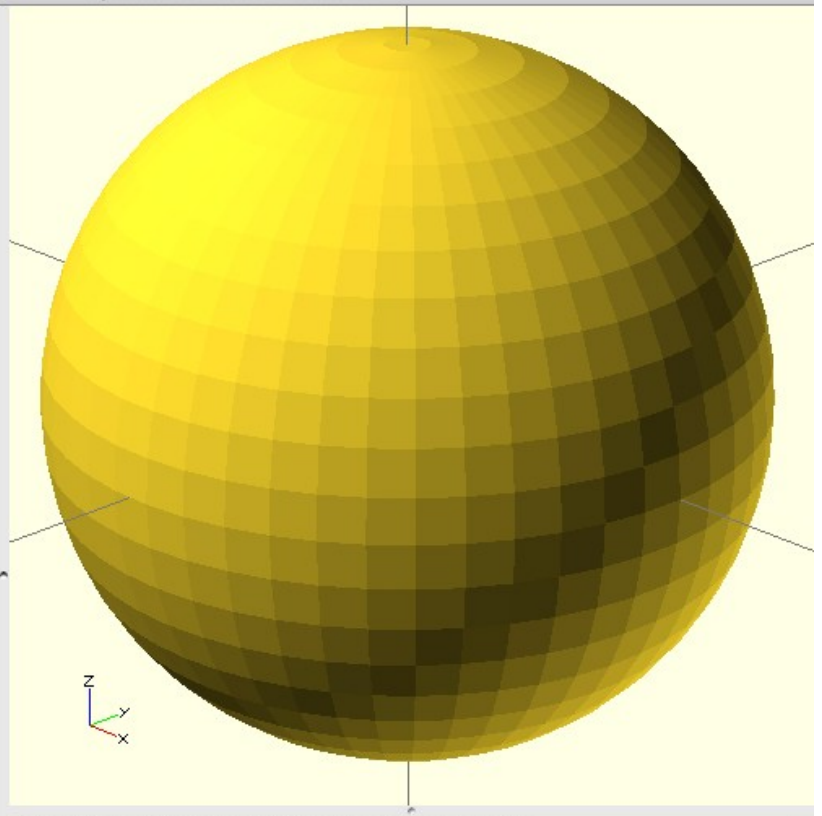

```
cylinder(
  h  = 20,
  r  = 15,
  $fs= 2);
```



Sphere

```
sphere(
   r = 5,
   $fn=50);
```

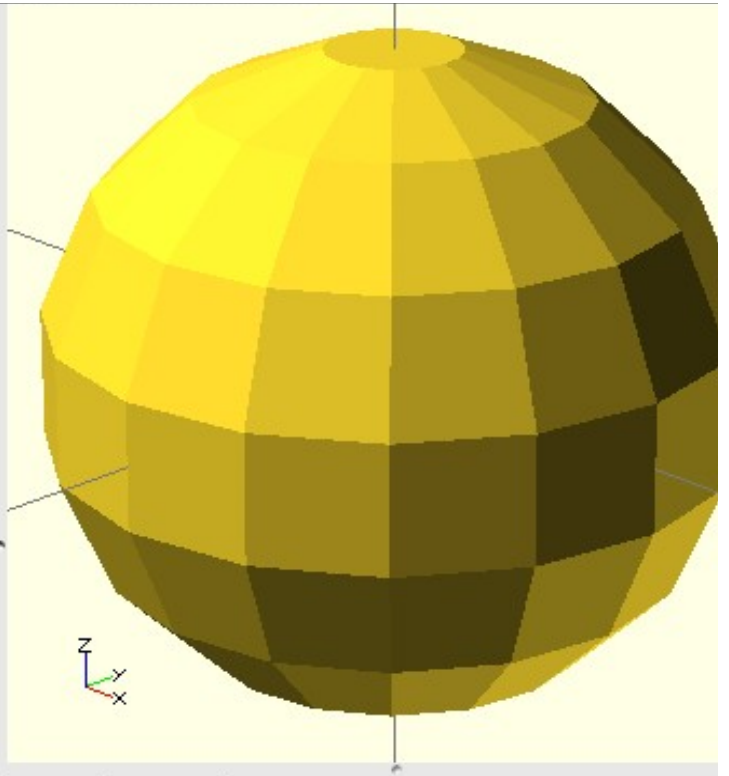
OpenSCAD – New Document



```
Number of objects currently in CGAL cache: 15
  Top level object is a 3D object:
  Simple:       yes
  Valid:        yes
  Vertices:     1250
  Halfedges:    7204
  Edges:        3602
  Halffacets:   4708
  Facets:       2354
  Volumes:      2
Total rendering time: 0 hours, 0 minutes, 4 seconds
Rendering finished.
```

Viewport: translate = [-31.67 31.20 -18.49], rotate = [67.60 0.00 45.50], distance = 102.95

```
here(r = 5);
```



```
  Valid:        yes
  Vertices:     128
  Halfedges:    672
  Edges:        336
  Halffacets:   420
  Facets:       210
  Volumes:      2
Total rendering time: 0 hours, 0 minutes, 0 second
```

Transformations

- Translate (move)
- Rotate

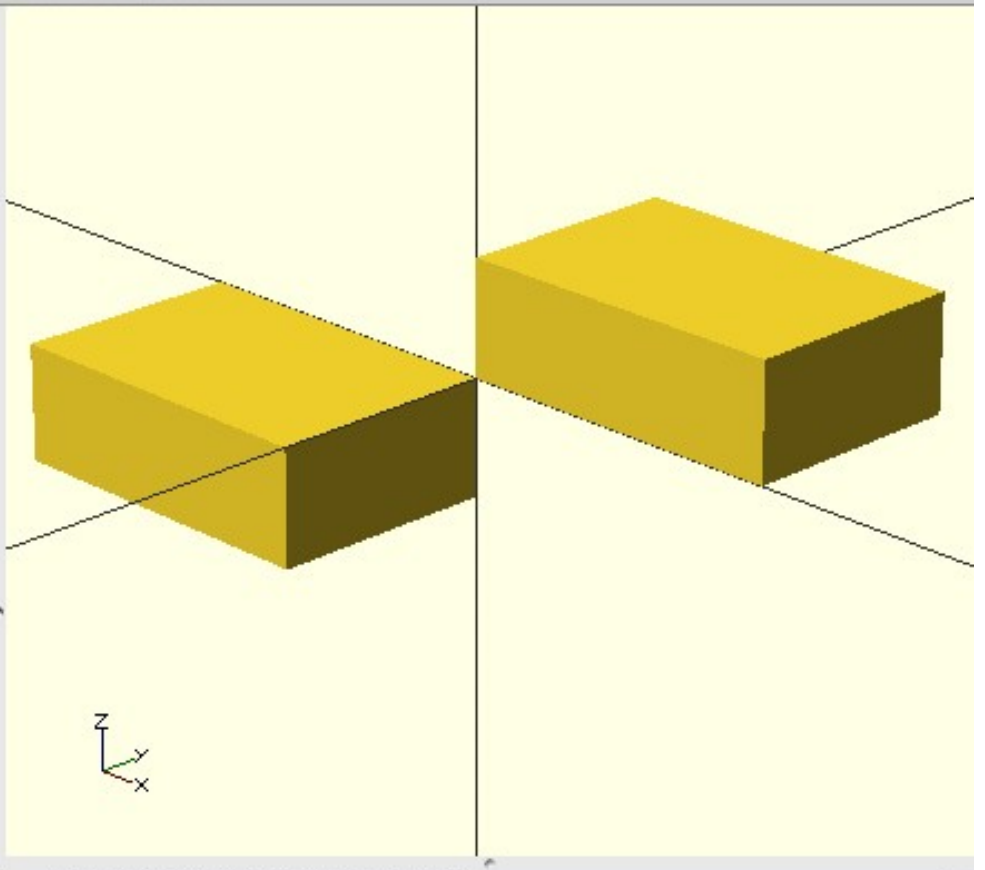
Translate

OpenSCAD – New Document

```
module mycube()
{
   cube(
      size = [3,2,1]
      );
}

mycube();

translate([-3,-2,-1])
   mycube();
```



Top level object is a 3D object:
Simple: no
Valid: yes
Vertices: 15
Halfedges: 48
Edges: 24
Halffacets: 24
Facets: 12
Volumes: 3
Total rendering time: 0 hours, 0 minutes, 0 seconds

Viewport: translate = [-31.57 31.17 -18.73], rotate = [67.60 0.00 45.50], distance = 83.39

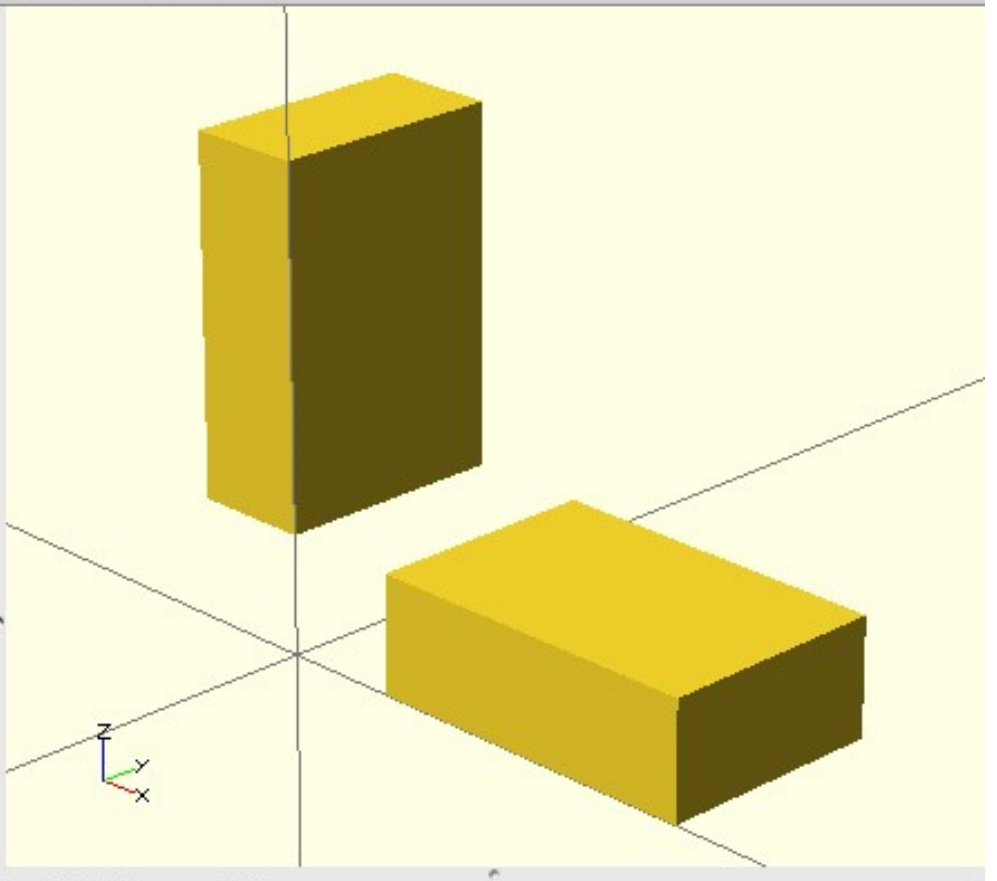
Rotate

OpenSCAD – New Document

```
module mycube()
{
  translate([1,0,0])
  cube(
    size = [3,2,1]
    );
}

mycube();

rotate([0,-90,0])
  mycube();
```



```
Simple:     yes
Valid:      yes
Vertices:    16
Halfedges:   48
Edges:       24
Halffacets:  24
Facets:      12
Volumes:      3
Total rendering time: 0 hours, 0 minutes, 0 seconds
Rendering finished.
```

Viewport: translate = [-31.14 32.74 -16.80], rotate = [67.60 0.00 45.50], distance = 83.39

Constructive Solid Geometry (CSG)

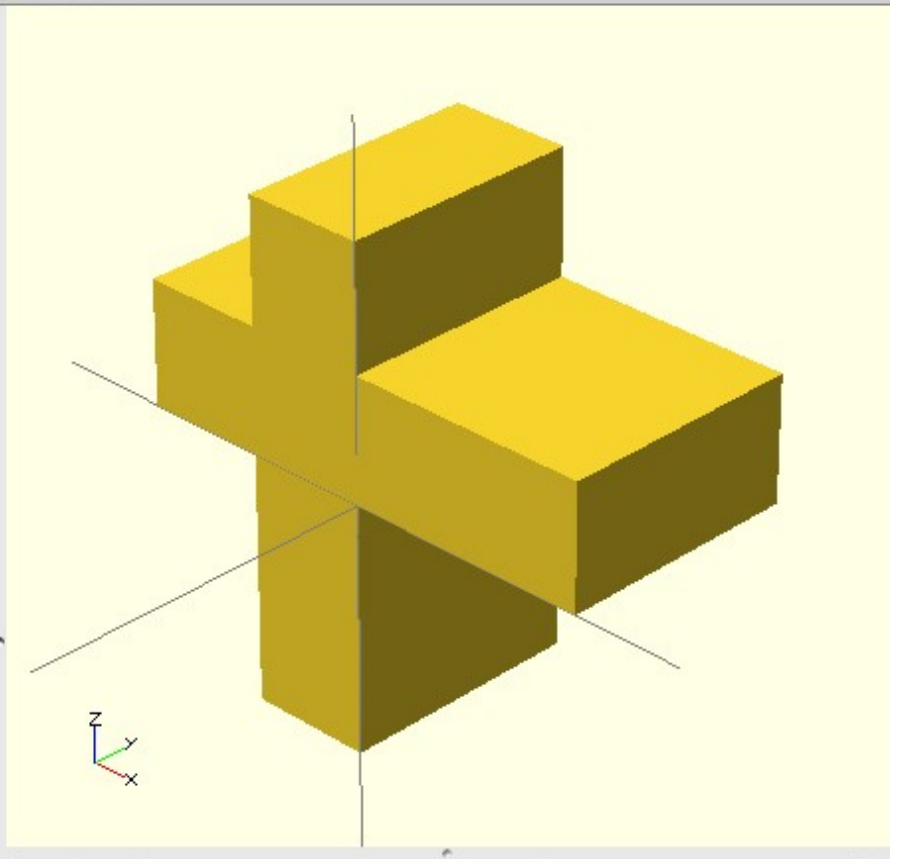
- Like 3D Venn Diagrams
- Boolean combinations of 3D objects
- Union
- Intersection
- Difference

Union

OpenSCAD – New Document

```
module mycube()
{
  translate([-2,0,0])
    cube( size=[4,2,1] );
}

union()
{
  mycube();
  rotate([0,-90,0])
    mycube();
}
```



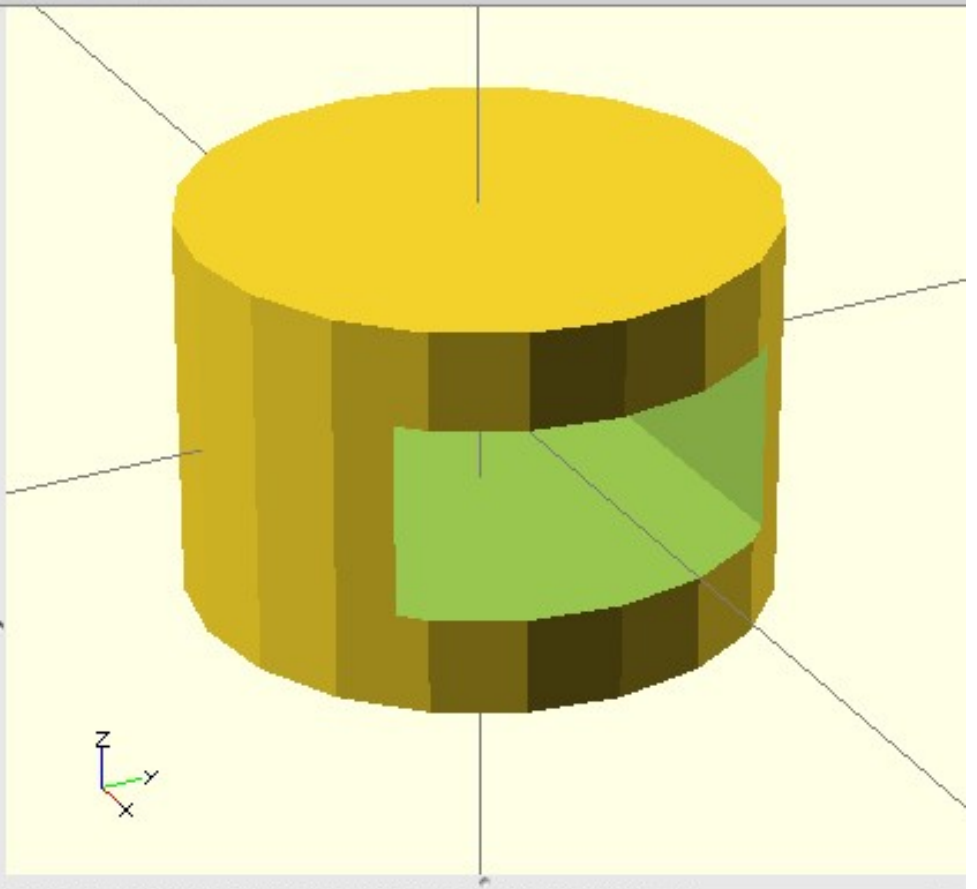

```
Number of vertices currently in CGAL cache: 80
Number of objects currently in CGAL cache: 6
  Top level object is a 3D object:
  Simple:       yes
  Valid:        yes
  Vertices:      24
  Halfedges:     72
  Edges:         36
  Halffacets:    28
  Facets:        14
  Volumes:        2
Total rendering time: 0 hours, 0 minutes, 0 seconds
Rendering finished.
```

Viewport: translate = [0.25 0.62 0.47], rotate = [60.60 0.00 44.30], distance = 29.07

Difference

OpenSCAD - New Document

```
difference()
{
   cylinder(
      h = 2,
      r = 1.5,
      center = true,
      $fn = 20);
   cube(
      size = [3,2,1],
      center = true );
}
```



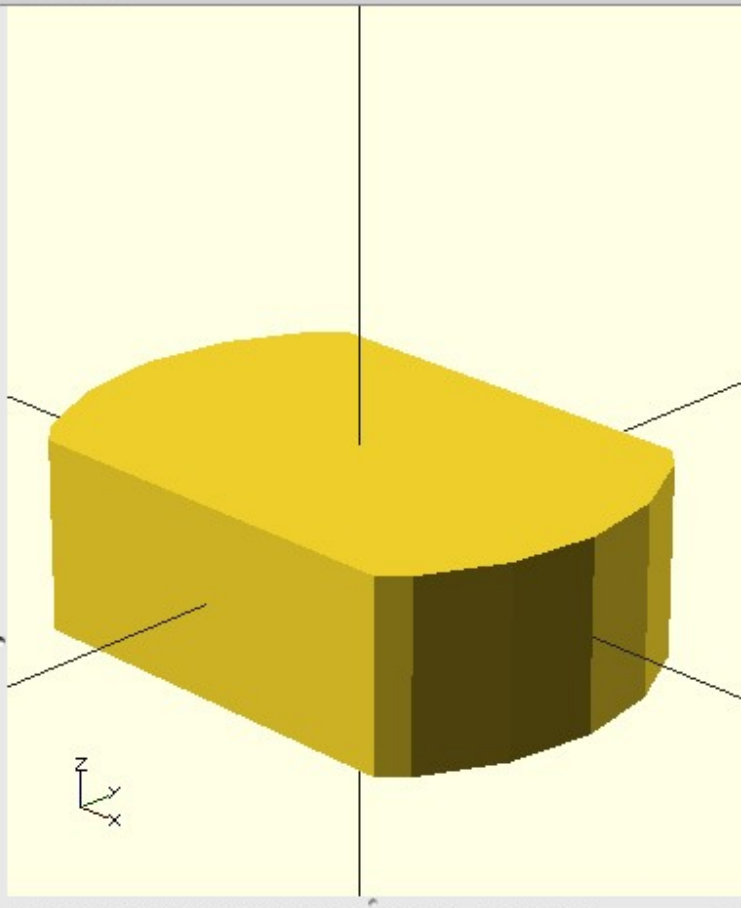
Top level object is a 3D object:
Simple: yes
Valid: yes
Vertices: 68
Halfedges: 204
Edges: 102
Halffacets: 68
Facets: 34
Volumes: 2

Viewport: translate = [-35.64 18.20 -20.33], rotate = [63.40 0.00 63.00], distance = 67.54

Intersection

OpenSCAD – New Document

```
intersection()
{
  cube(
    size = [3,2,1],
    center = true );
  cylinder(
    h = 2,
    r = 1.5,
    center = true,
    $fn = 20);
}
```



```
Top level object is a 3D object:
Simple:        yes
Valid:         yes
Vertices:       28
Halfedges:      84
Edges:          42
Halffacets:     32
Facets:         16
Volumes:         2
Total rendering time: 0 hours, 0 minutes, 0 seconds
Rendering finished.
```

Viewport: translate = [-31.28 31.60 -18.49], rotate = [66.90 0.00 44.80], distance = 67.54

The gotcha: non-manifold shapes

- Avoid Boolean combinations with co-incident surfaces
- These result in zero-thickness boundaries between objects, which computers cannot reliably represent
- UNION/DIFFERENCE objects should overlap
- See also: http://reprap.org/wiki/AoI

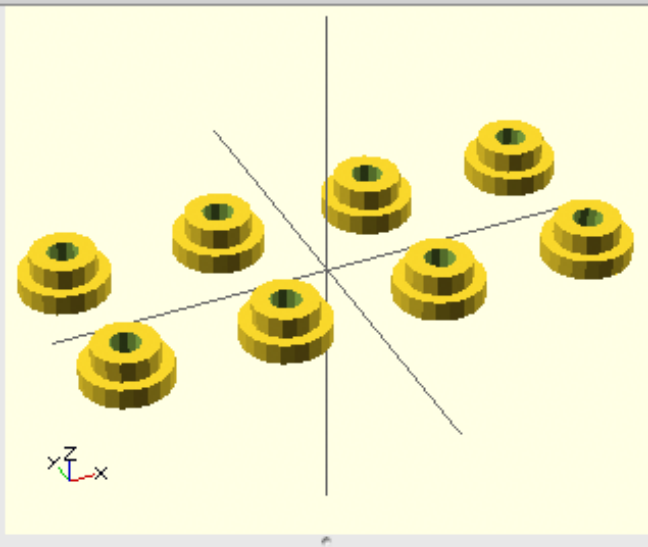
A very simple design

OpenSCAD – springseat.scad

```
// Single object
module springseat(od, id, boltd, totalh, flangeh)
{
  or = od/2;
  ir = id/2;
  br = boltd/2;
  difference()
  {
    union() {
      cylinder(r=ir, h=totalh);
      cylinder(r=or, h=flangeh);
    }
    translate([0,0,-6]) {
      cylinder(r=br, h=totalh+10, $fn=12);
    }
  }
}

// Main object array:
outerd = 13;
innerd = 9.5;
holed  = 4.5;   // +0.5 for M4 bolt
totalh = 6;
endh   = 3;

// Implicit union of all objects
pitch = outerd+10;
for (x = [-1.5*pitch,-0.5*pitch,0.5*pitch,1.5*pitch]) {
  for (y = [-0.5*pitch,0.5*pitch]) {
    translate([x,y,0]) {
      springseat(outerd, innerd, holed, totalh, endh);
    }
  }
}
```



```
Parsing design (AST generation)...
Compiling design (CSG Tree generation)...
Compilation finished.
Rendering Polygon Mesh using CGAL...
Number of vertices currently in CGAL cache:
8669
Number of objects currently in CGAL cache: 94
  Top level object is a 3D object:
  Simple:       yes
  Valid:        yes
  Vertices:     768
  Halfedges:    2304
  Edges:        1152
  Halffacets:   816
  Facets:       408
  Volumes:      9
Total rendering time: 0 hours, 0 minutes, 9
seconds
Rendering finished.
```

Viewport: translate = [0.00 0.00 0.00], rotate = [55.00 0.00 335.00], distance = 405.00

http://pif3d.googlecode.com/hg/Objects/SpringSeat/springseat.scad

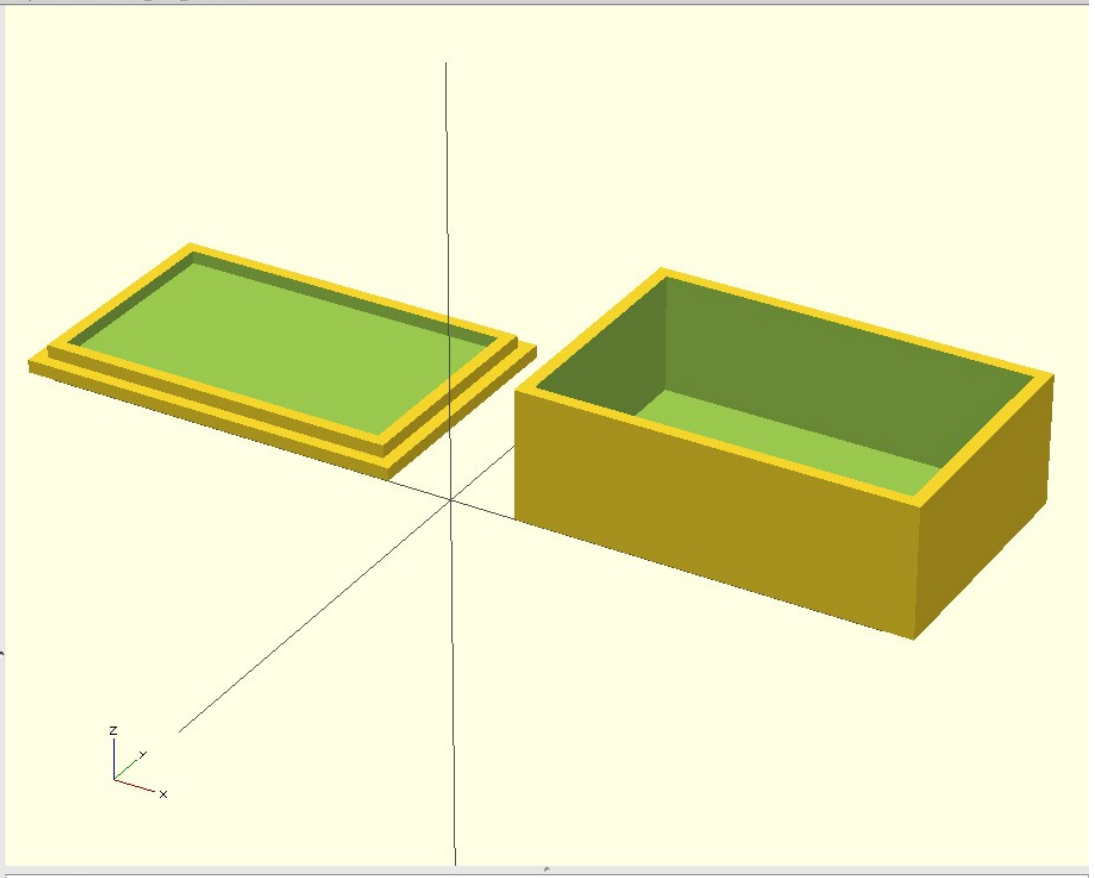
Making it real...

OpenSCAD – box_and_lid.scad

```
module box(l, w, h, t)
{
  t2 = t * 2;
  difference()
  {
    cube( size=[l,w,h] );
    translate([t,t,t])
      cube( size=[l-t2, w-t2, h-t]) ;
  }
}
module lid(l, w, t)
{
  t2 = t * 2;
  t4 = t * 4;
  difference()
  {
    union()
    {
      cube( size=[l, w, t] );
      translate( [t, t, t*0.5] )
        cube( size=[l-t2, w-t2, t*1.5] );
    }
    translate( [t2, t2, t] )
      cube( size=[l-t4, w-t4, t2] );
  }
}
module support(dl, dw, h, od, id)
{
   // TBD: PCB support posts
}

module case()
{
   // TBD: case with PCB and lid attachment supports
}

// Try it out
l = 30;      // Length
w = 20;      // Width
h = 10;      // Height
t = 1;       // Wall thickness
s = 5;       // Spacing
translate([s,0,0])
  box(l, w, h, t);
translate([-s-l, 0, 0])
  lid(l, w, t);
```




```
Parsing design (AST generation)...
Compiling design (CSG Tree generation)...
Compilation finished.
Rendering Polygon Mesh using CGAL...
Number of vertices currently in CGAL cache: 1030
Number of objects currently in CGAL cache: 66
  Top level object is a 3D object:
  Simple:        yes
  Valid:         yes
  Vertices:       40
  Halfedges:     120
  Edges:          60
  Halffacets:     54
  Facets:         27
  Volumes:         3
Total rendering time: 0 hours, 0 minutes, 0 seconds
Rendering finished.
```

Viewport: translate = [4.03 6.02 3.22], rotate = [59.90 0.00 30.30], distance = 328.05

Sources

- Slides:

  http://pif3d.googlecode.com/hg/Presentations/20111025-OpenSCAD.odp

  http://pif3d.googlecode.com/hg/Presentations/20111025-OpenSCAD.pdf

- Spring seat design:

  http://pif3d.googlecode.com/hg/Objects/SpringSeat/springseat.scad

- Electronics case design:

  http://pif3d.googlecode.com/hg/Objects/ElectronicsCase/box_and_lid.scad

See also

- http://edutechwiki.unige.ch/en/OpenScad_beginners_tutorial
- http://en.wikibooks.org/wiki/OpenSCAD_User_Manual
- ...