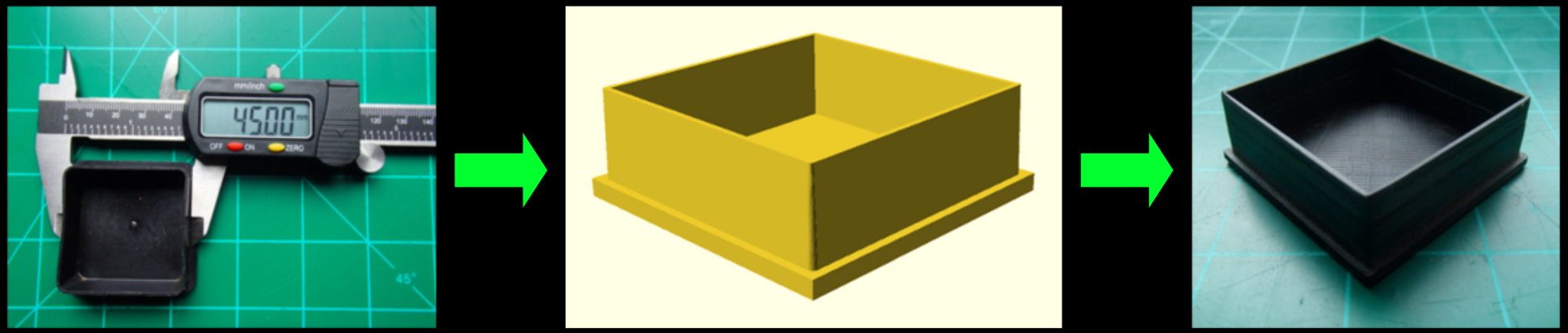
Reverse Engineering using OpenSCAD & 3D Printing



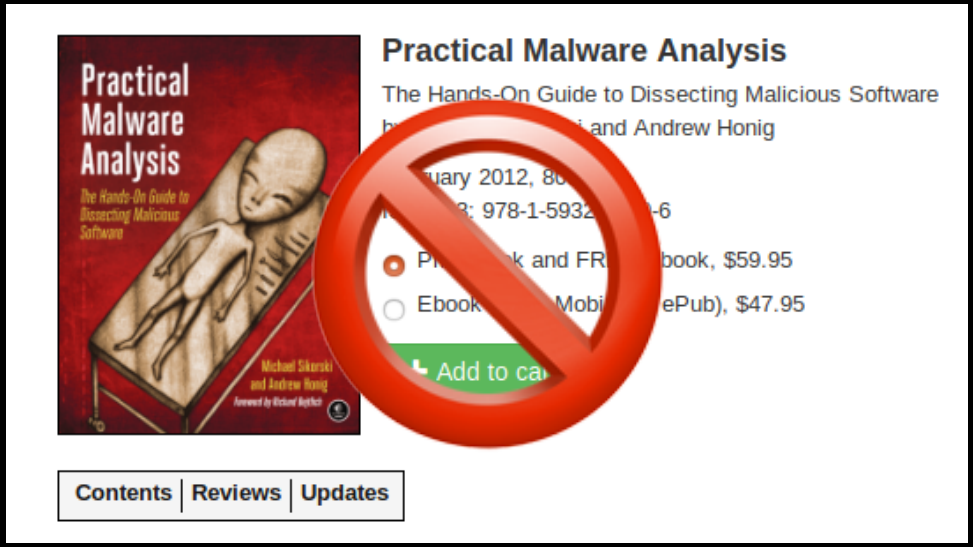
Expectations

- 45 min intro
  - Reverse Engineering
  - 3D Printing toolchain
  - Process
- OpenSCAD training
  - Hands-on-keyboard practice
  - A few short breaks
- Questions welcome anytime



NOT covered

- Locksmith & picking
- Software
  - Malware analysis
  - Cracking DRM
  - Patent evasion
- Forensics
  - NTSB plane crash
  - CSI homicide
  - FBI digital intrusion



Prizes

- Challenge coins & Stickers



- Awarded for interesting questions or solutions

Photos

✔ Do post:

- Me
- Yourself
- Your own work

✖ Do NOT post:

- Other students
- Things you didn’t create

Tag @nickthetait on twitter

Oldsk00l? ➡ ask for my email address





Reference material

- Available here ➡
- Contains
  - These slides
  - Solutions to assignments
  - OpenSCAD manual



also here if your fingers are feeling energetic ➡ https://gitlab.com/nickthetait/talks/

Professional Bio

- “nickthetait” aka Nick Tait
- Software Engineer
  - Open source
  - Python
- Previously worked on
  - 3D Printers
  - Delivery services
- Next job ➡ cybersecurity



Personal Bio

Warranty wreckin’ Colorado resident

LEGO buildin’ mountain biker

Tea sippin’ rock climber

Video gamin’ metalhead

14er hikin’ thing fixer

Spanish speakin’ amateur chef

World travelin’ emoji spammer

Lock pickin’ encryption enthusiast



Me in two words

```
layabout millennial ➡
```



Disclaimer

- I am not an attorney
- Understanding the law is your responsibility!





What

reverse engineer

verb

Popularity: Bottom 40% of words | Updated on: 8 Jun 2018

Definition of REVERSE ENGINEER

transitive verb

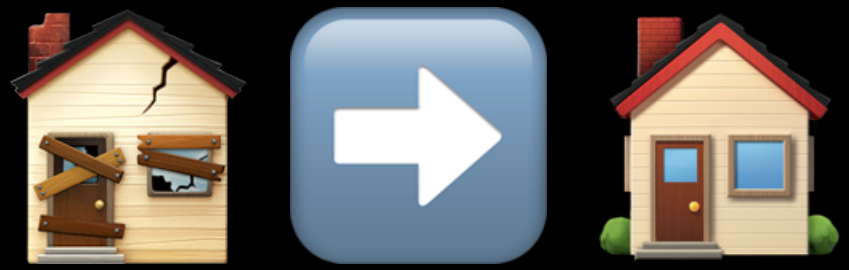
: to disassemble and examine or analyze in detail (a product or device) to discover the concepts involved in manufacture usually in order to produce something similar

Goal

- Identical replacement
- Adapt / Improve
- Learn new tool or process

Why

- Repair
- Interoperability
- Obsolescence
- Commercial usage

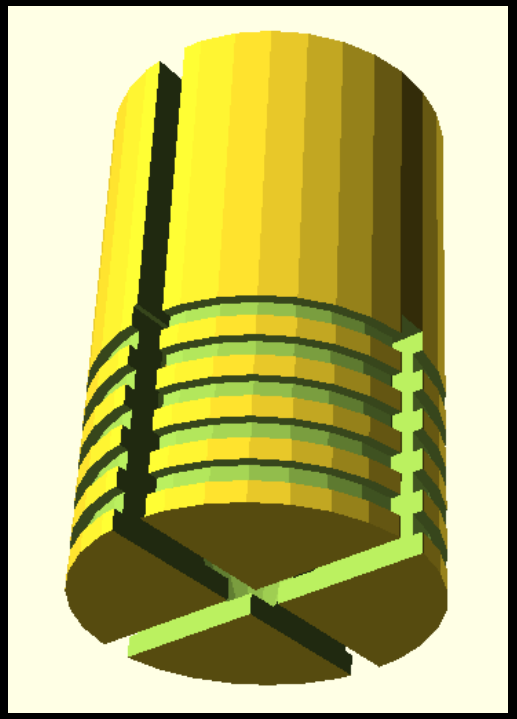


Repair

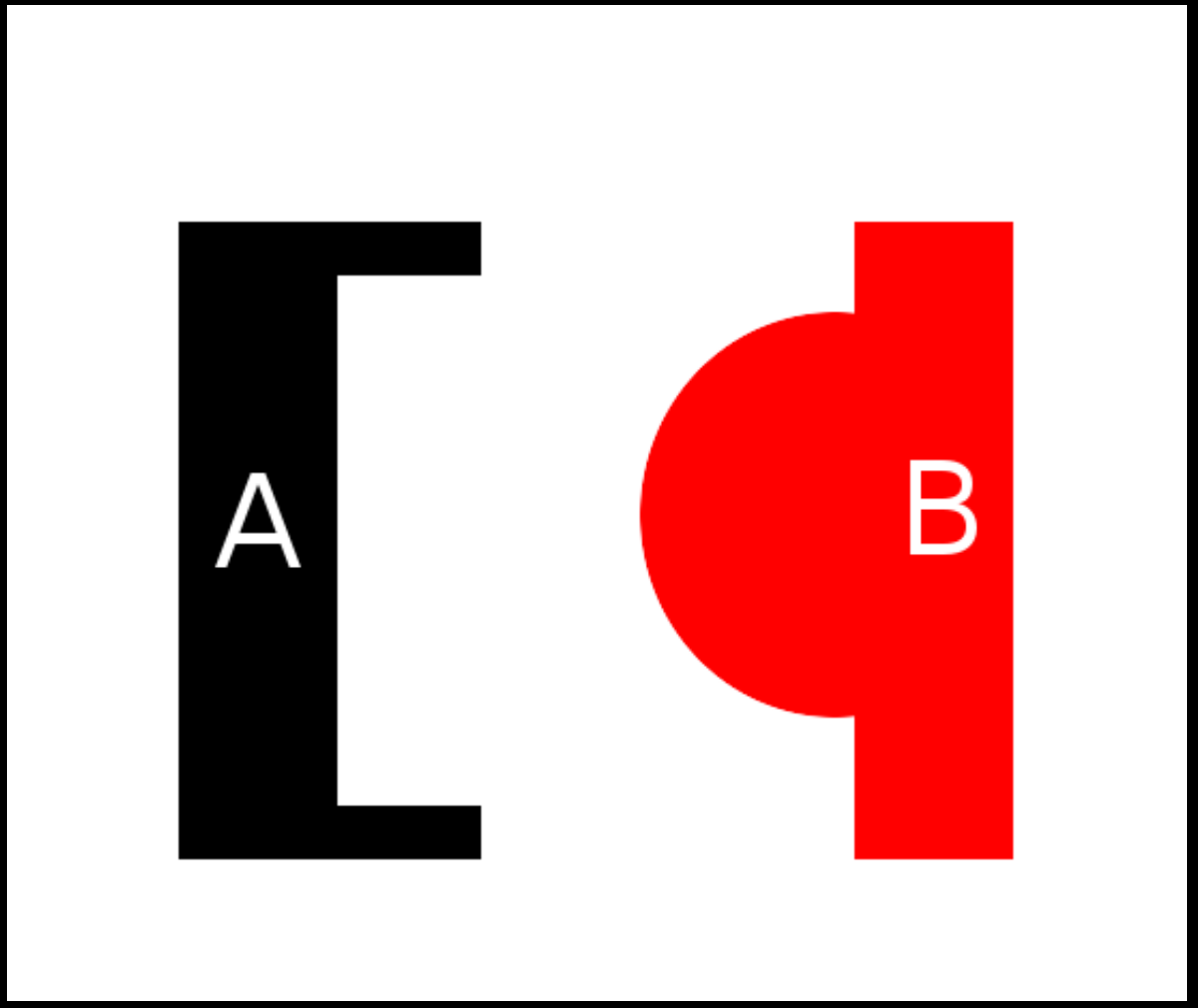


Repair

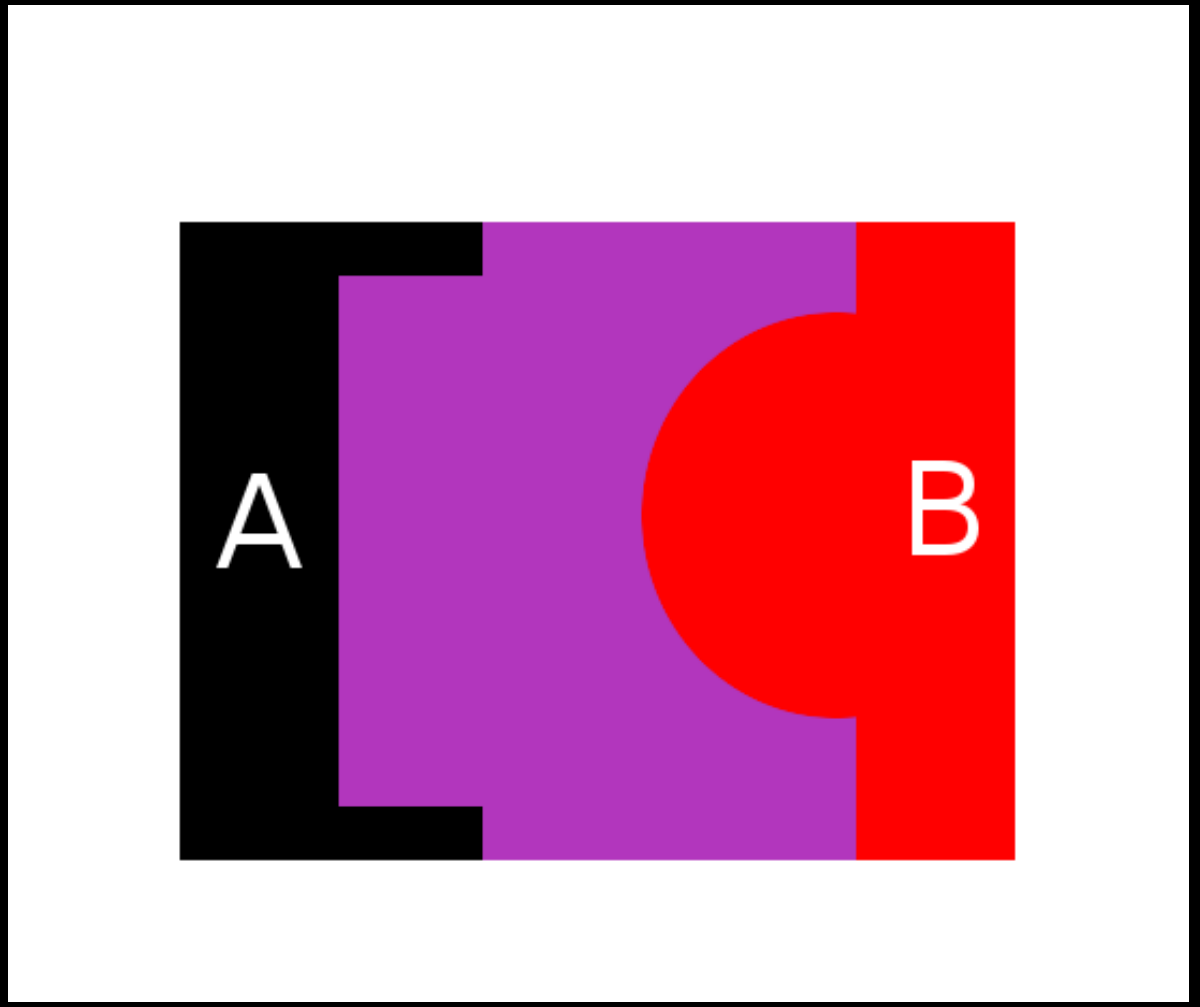




Interoperability

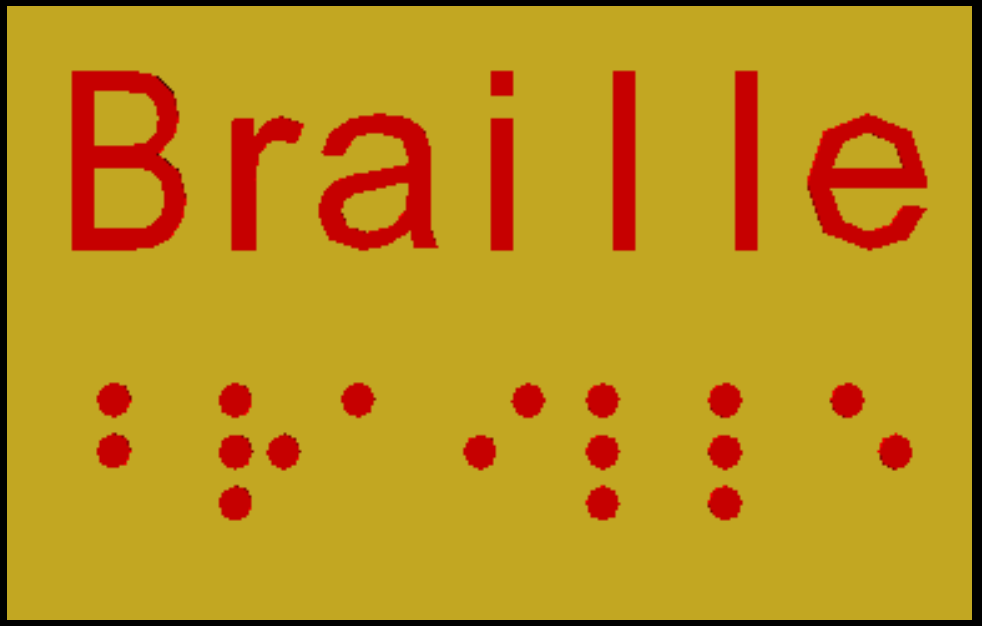


Interoperability



Accessibility





Obsolescence

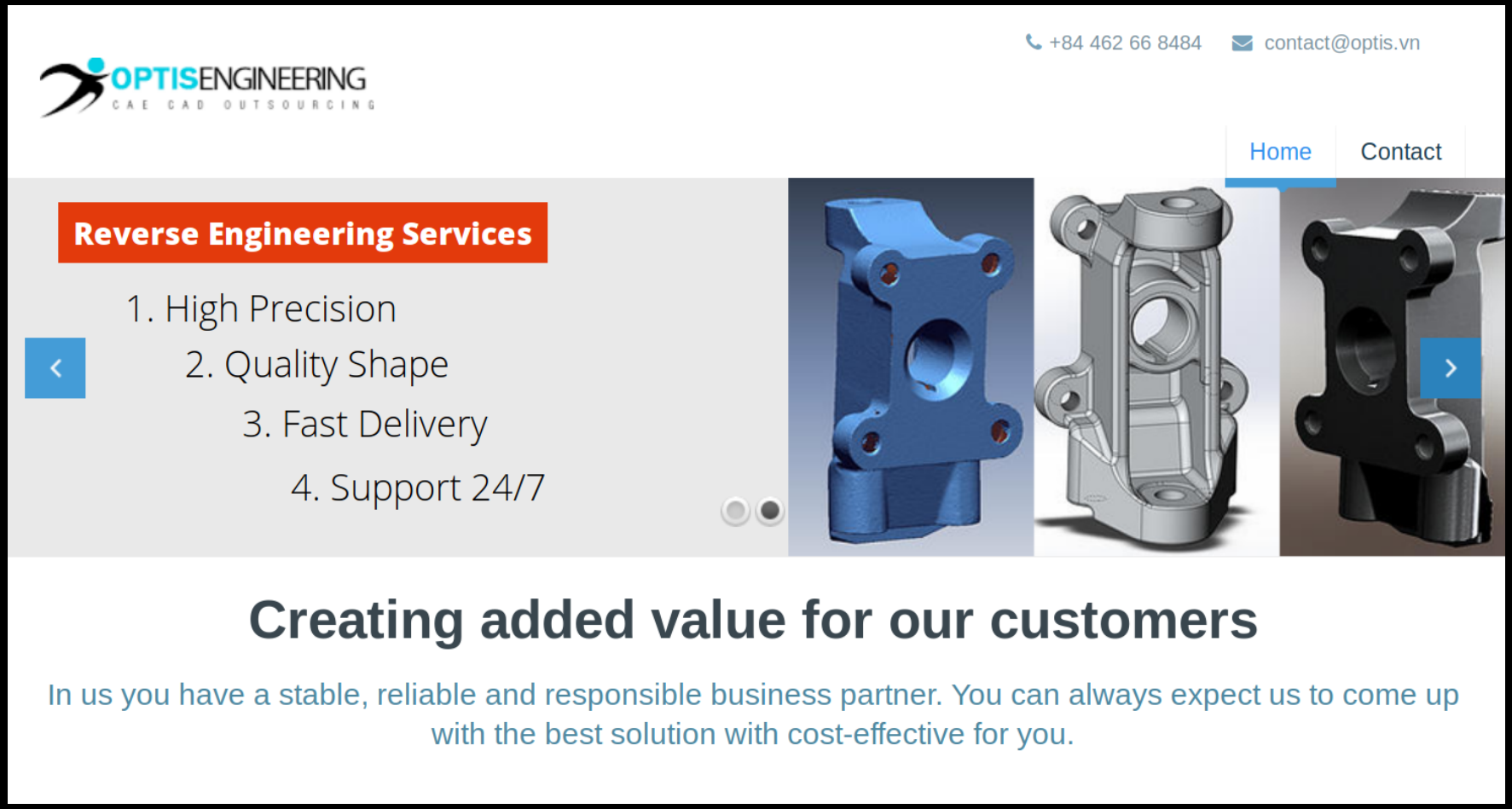
- Individual sub-component
- Entire system



Commercial Use

- Loss of original design ¯_(ツ)_/¯
- Legacy product modernization
  - New manufacturing methods
  - Cost saving
- Healthy competition

Commercial Use

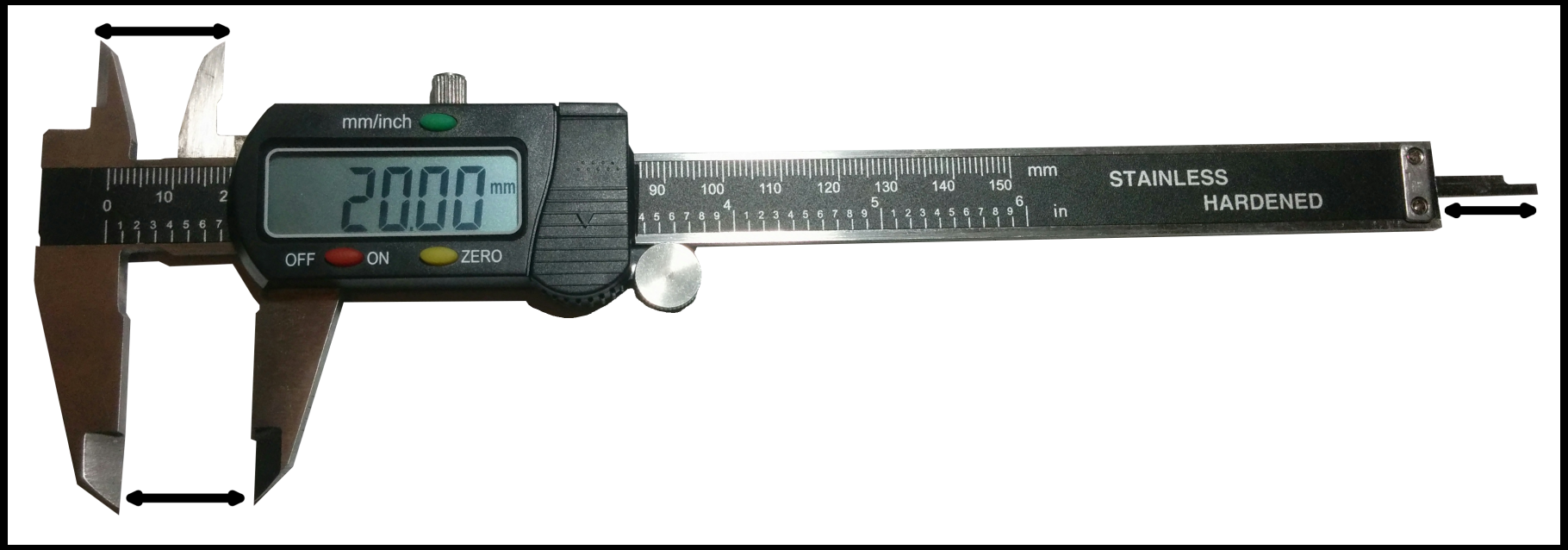


How

- Tools
  - Measurement
  - Design
  - Production
- Process



Digital Calipers



OpenSCAD

Editor

```
$fn = 100;
radius = 30;
structureHeight = 5;
detailHeight = 2;
rimThickness = 2;

module structure()
{
    cylinder
    (
        structureHeight,
        radius,
        radius,
        center = false
    );
}

module bothSurfaceDetails
(
    message,
    positiveText
)
{
    //Top
    singleSurfaceDetail
    (
        ZPosition   =   structureHeight,
        positiveText = positiveText,
        message = message
    );

    //Bottom
    singleSurfaceDetail
    (
        ZPosition   =   - detailHeight,
        positiveText = positiveText,
```



Console

```
CGAL cache size in bytes: 18610704
Total rendering time: 0 hours, 0 minutes, 16 seconds
  Top level object is a 3D object:
  Simple:      yes
  Vertices:    1936
  Halfedges:   5808
  Edges:       2904
  Halffacets:  1972
  Facets:      986
  Volumes:     2
Rendering finished.
```

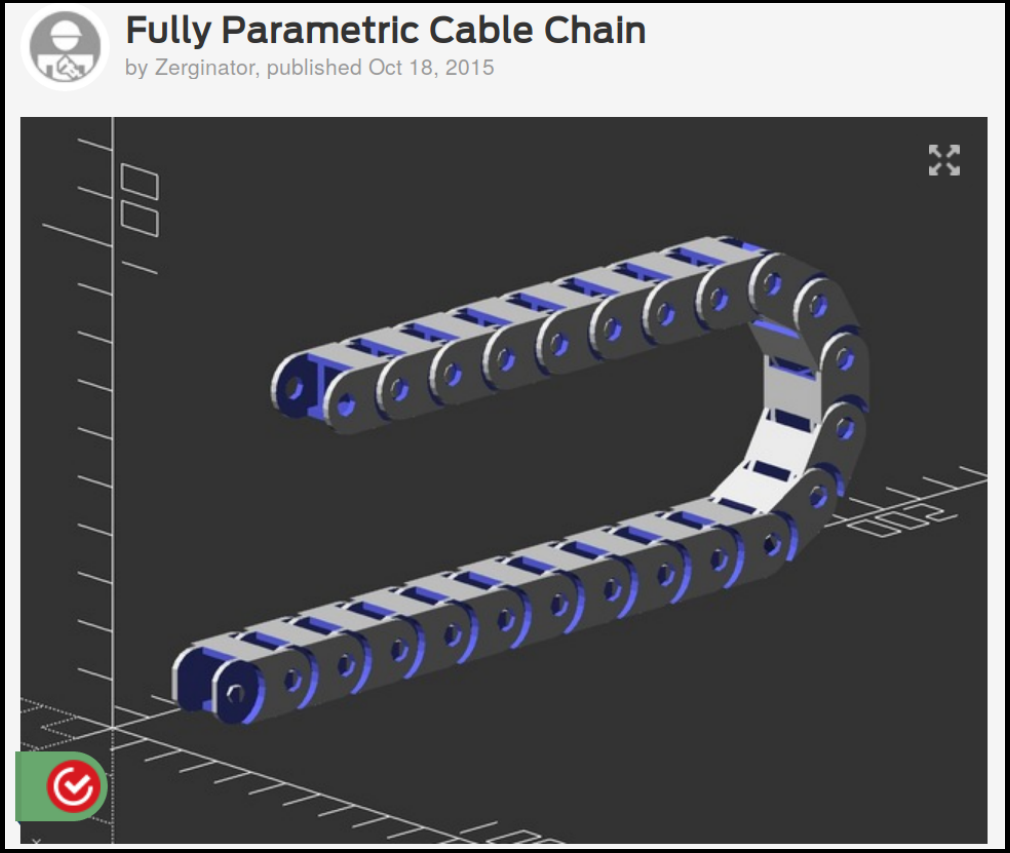
Viewport: translate = [4.99 1.08 -1.43], rotate = [43.80 0.00 339.50], distance = 155.56

OpenSCAD 2015.03

OpenSCAD

- Free as in Pizza
- Freedom to:
  - Use for any purpose
  - Make changes
  - Share with anyone
- Cross-platform
- Built and supported by the community
- No internet connection required
- Parametric

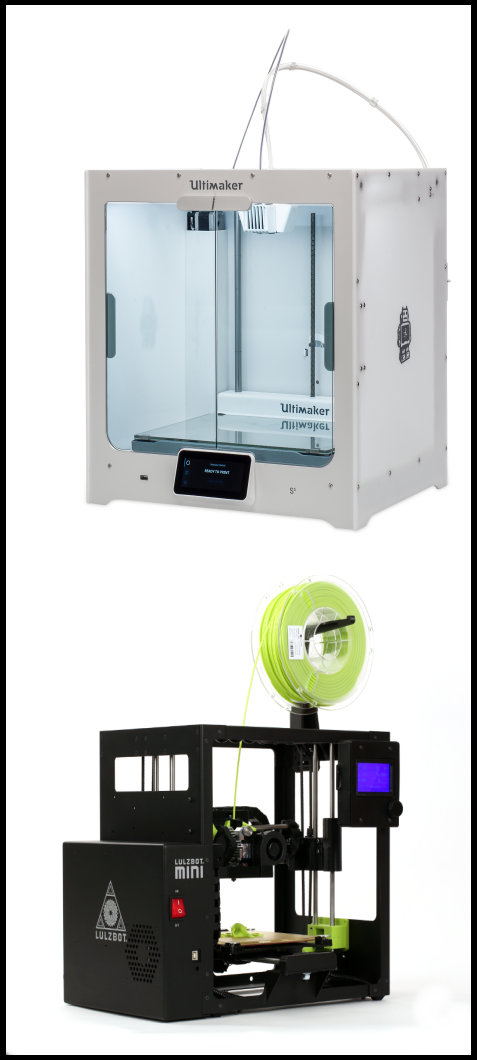
OpenSCAD


Fully Parametric Cable Chain
by Zerginator, published Oct 18, 2015


ISO/UTS thread OpenSCAD library
by RevK, published Mar 7, 2017

3D Printers

- Good
  - High customization
  - Wide variety of materials/strengths
  - Low operating and raw materials cost
- Bad
  - Relatively slow
  - No discount for volume
  - Limited build area



Process

- Research
- Measure
- Decompose
- Design
- Produce
- Test

Research

- Has this problem been solved before?
- Can I re-use part of someone's work?
- Starting places
  - Thingiverse.com
  - Youmagine.com
  - Reddit.com/r/functionalprint



Measure

- Reference point
- Orientation
- Dimensions
- Disassembly
  - Harmless
  - Destructive
- Sketch



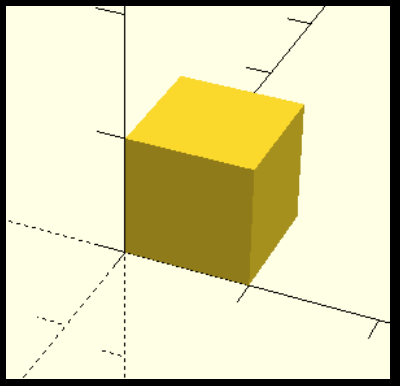


Decompose

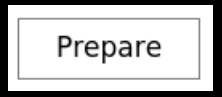


Design

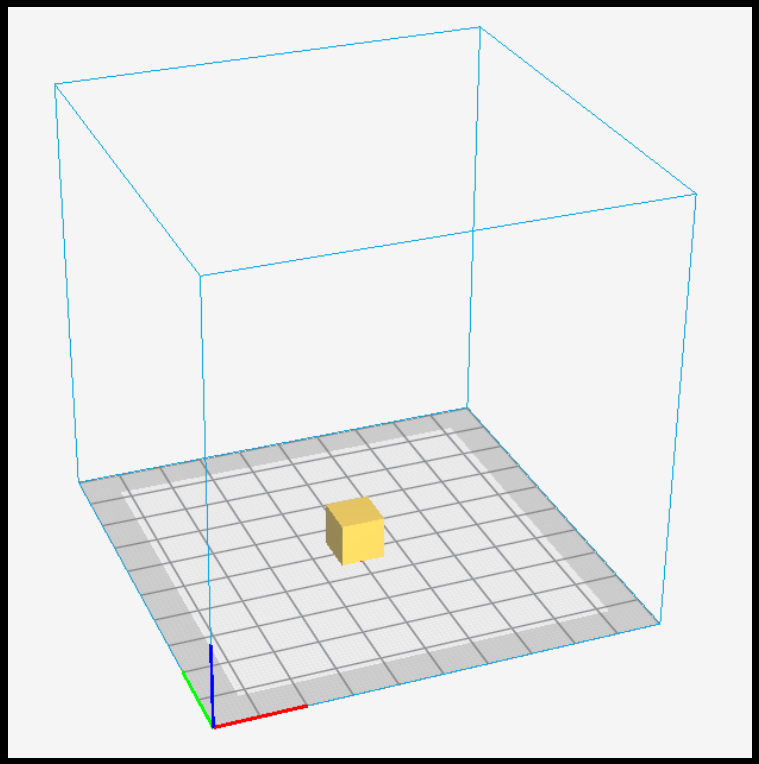
- Launch OpenSCAD
- Enter “Cube(10);” into text panel on the left side
- Press F5 or click “preview” 
- Press F6 or click “render” 
- Allow process to complete…
- File ➡ Export ➡ STL or click “export to STL” 



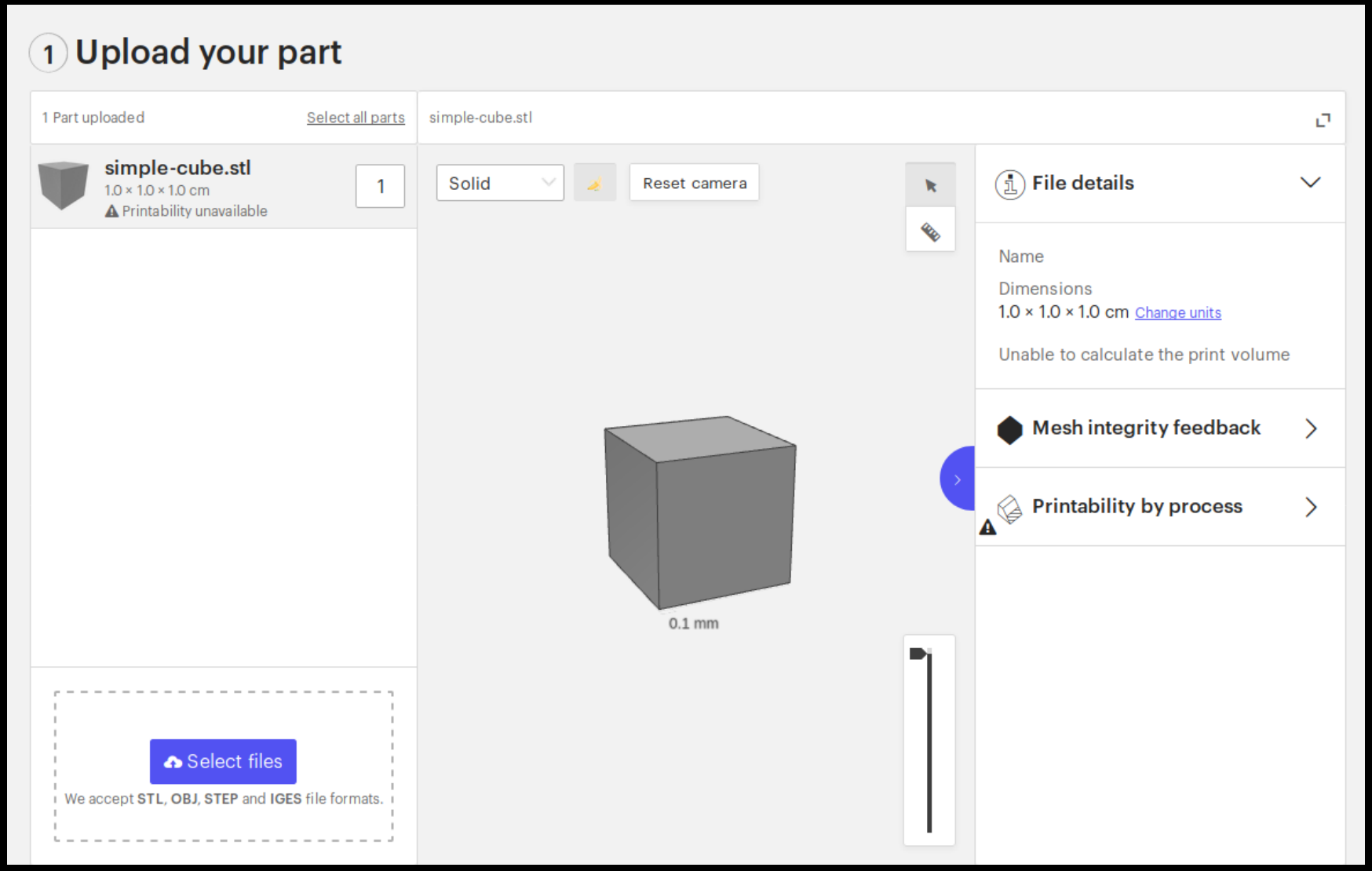
Produce

- Using your own 3D printer
- Launch Cura
- File ➡ Open files… 
- Select material & quality settings
- Click “Prepare” 

- Print!



Produce


1 Upload your part
1 Part uploaded
Select all parts
simple-cube.stl
simple-cube.stl
1.0 × 1.0 × 1.0 cm
Printability unavailable
1
Solid
Reset camera
File details
Name
Dimensions
1.0 × 1.0 × 1.0 cm Change units
Unable to calculate the print volume
Mesh integrity feedback
Printability by process
0.1 mm
Select files
We accept STL, OBJ, STEP and IGES file formats.

Produce

2 Select a material

Search materials: e.g. SLS, Accura 25 or Material Jetting

Both | Plastic | Metal

Material

- ○ PLA
- ○ ABS
- ○ Resin
- ◉ Nylon
- ○ PETG
- ○ TPU
- ○ ASA
- ○ PEI
- ○ Stainless steel
- ○ Aluminum

Advanced Options >



Standard Nylon

SLS

Standard Nylon (SLS) - PA 12 - has all-around great mechanical properties and chemical resistance and is ideal for functional parts and prototypes.

✓ 1 part is printable with SLS.

Color	**No Preference**
Layer height	**100 µm**

Get it by	Price
SOON!	**$ 20.00**

Continue to checkout

Process

- Research
- Measure
- Decompose

- Design
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- Test

Process

- Research
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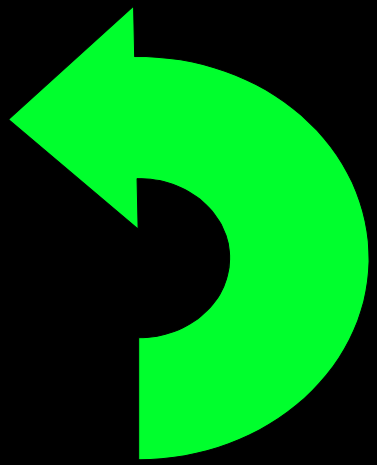
- Design
- Produce
- Test



What failed?

Why did it fail?

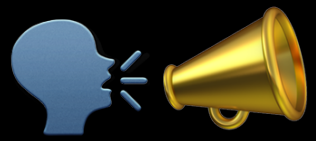
How to improve?

Celebrate

- Publish



- Tell the world

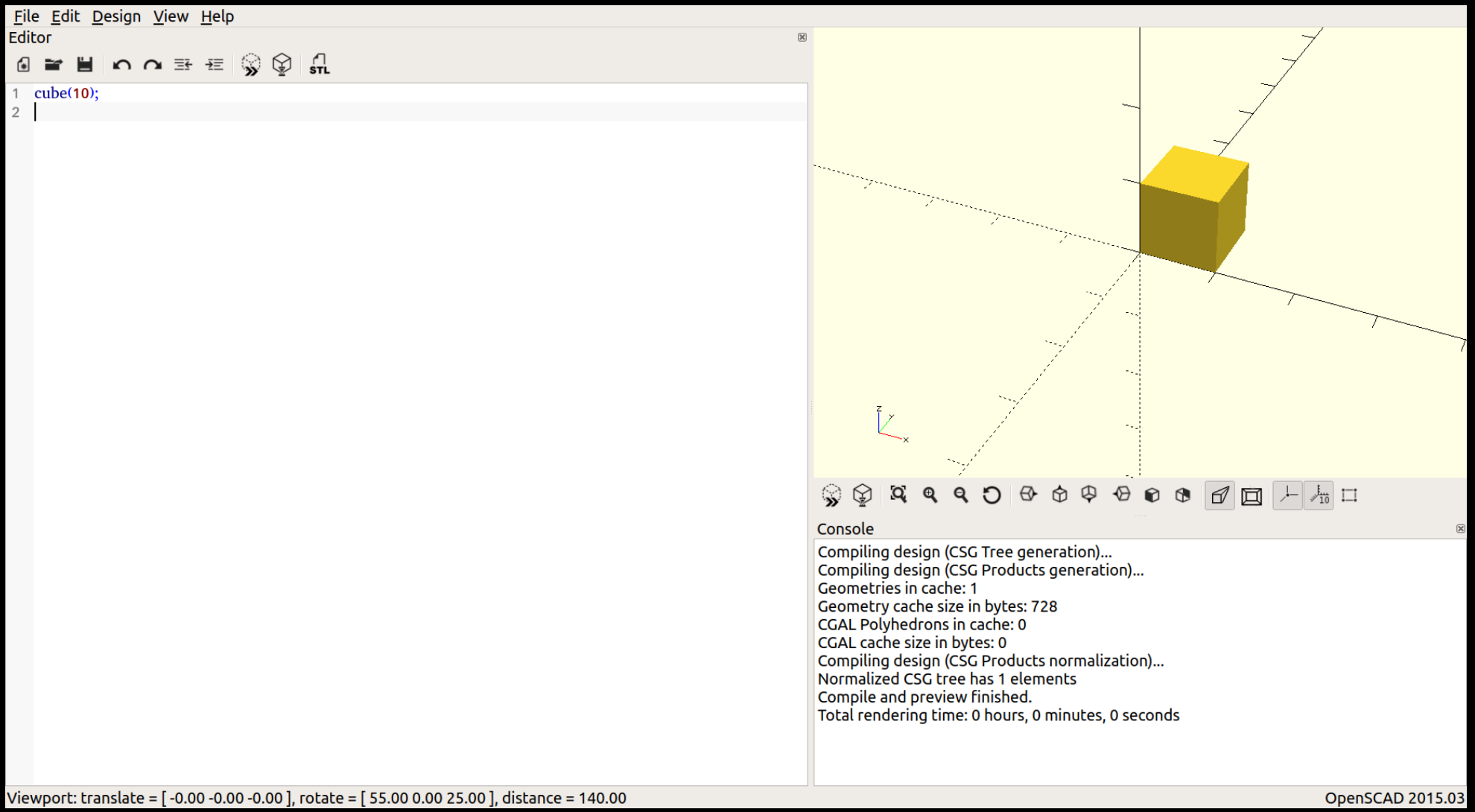


- Victory dance

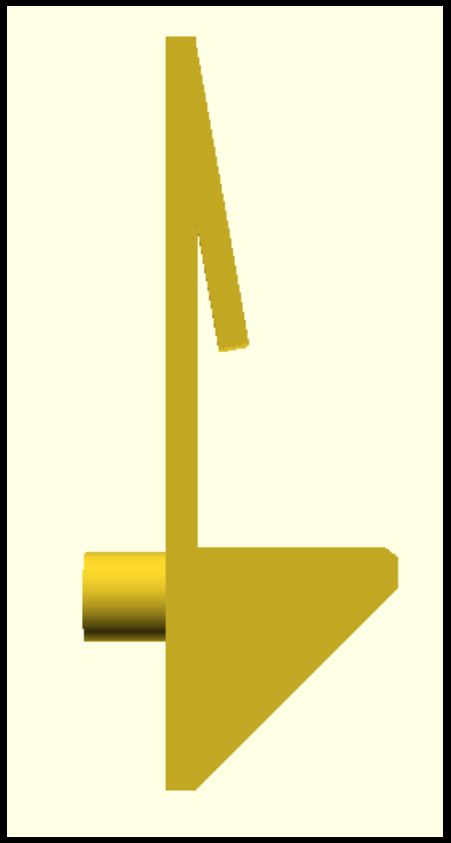


OpenSCAD!

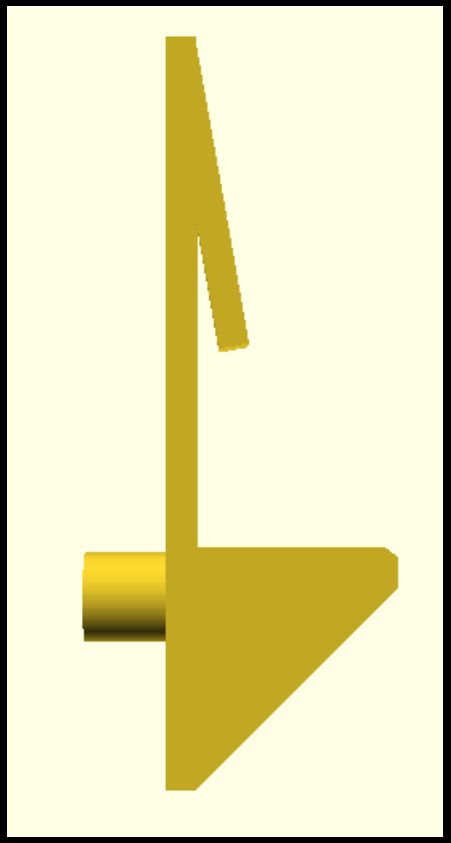
Interface

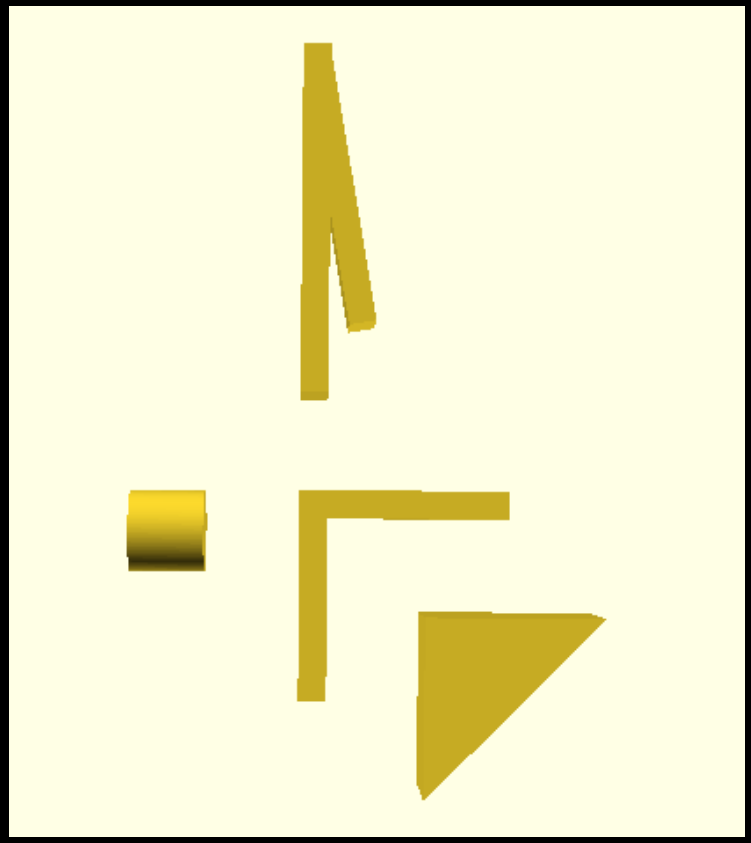

File Edit Design View Help
Editor
STL
1 cube(10);
2
Console
Compiling design (CSG Tree generation)...
Compiling design (CSG Products generation)...
Geometries in cache: 1
Geometry cache size in bytes: 728
CGAL Polyhedrons in cache: 0
CGAL cache size in bytes: 0
Compiling design (CSG Products normalization)...
Normalized CSG tree has 1 elements
Compile and preview finished.
Total rendering time: 0 hours, 0 minutes, 0 seconds
Viewport: translate = [-0.00 -0.00 -0.00], rotate = [55.00 0.00 25.00], distance = 140.00
OpenSCAD 2015.03

Decompose

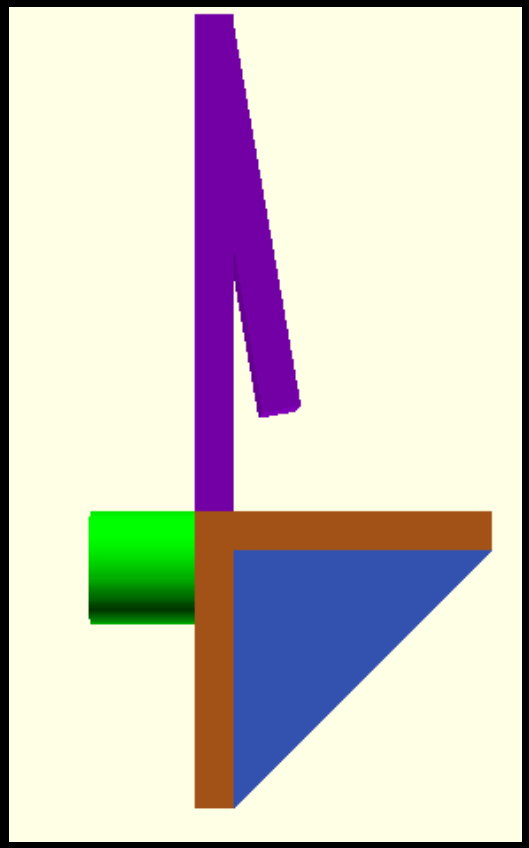


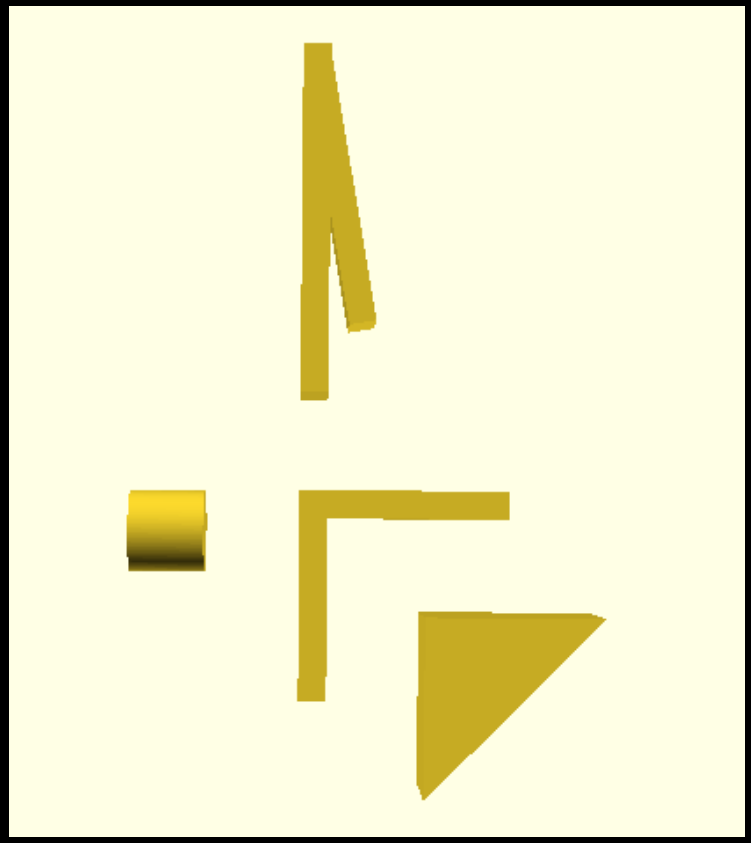
Decompose

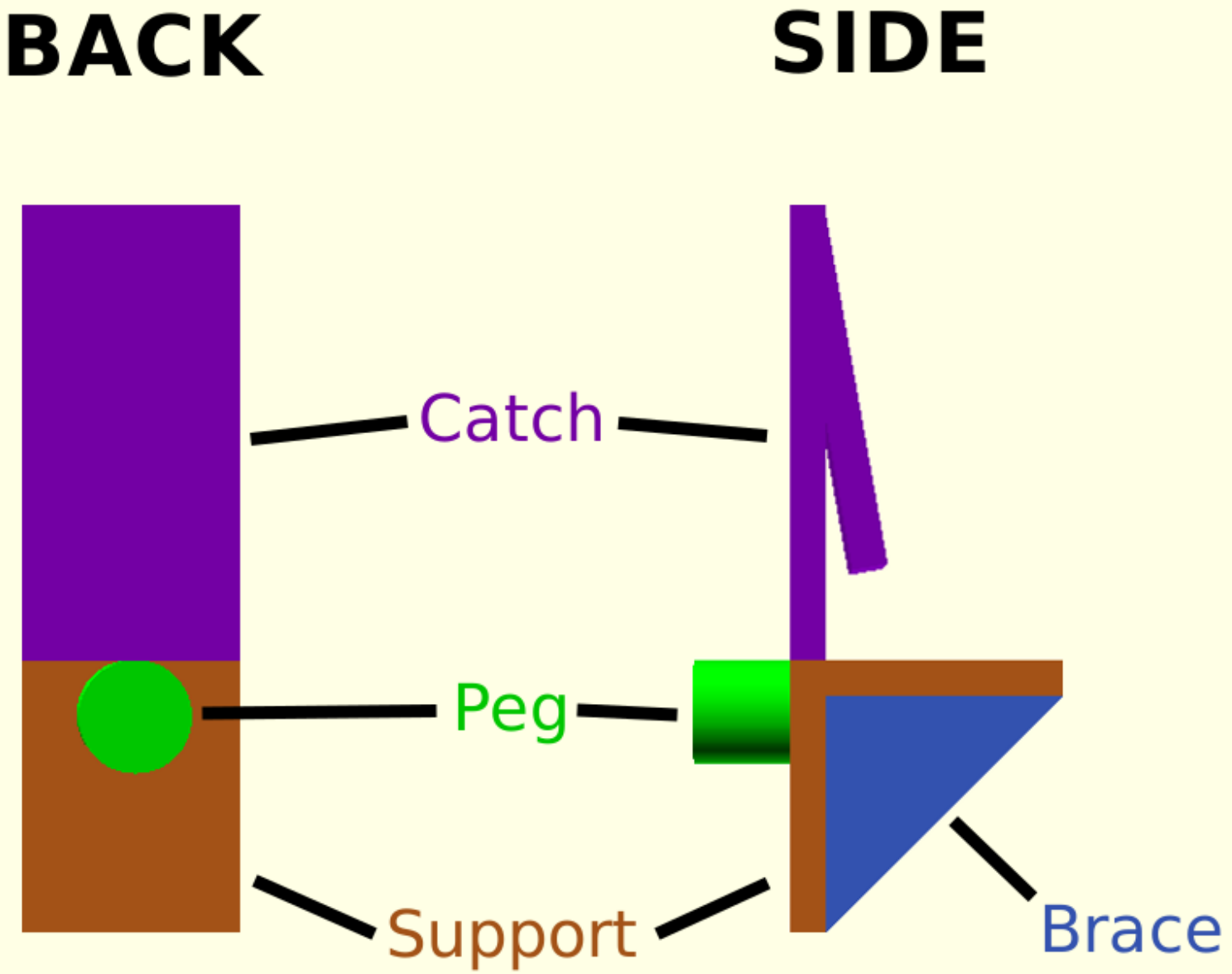




Decompose



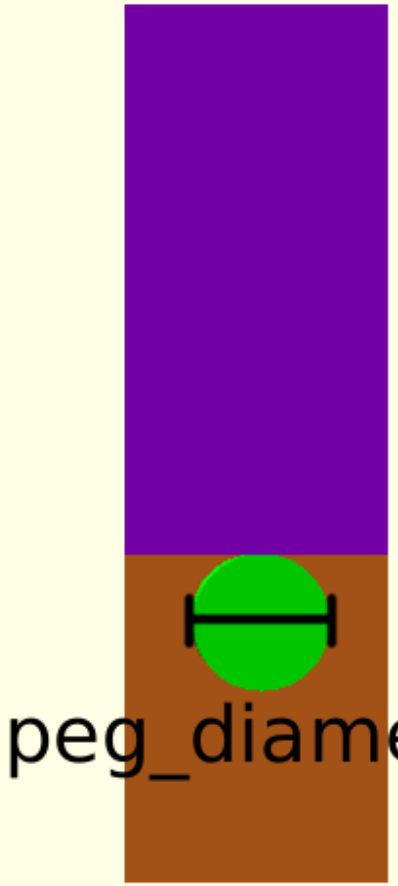



BACK
SIDE
Catch
Peg
Support
Brace

Training 1

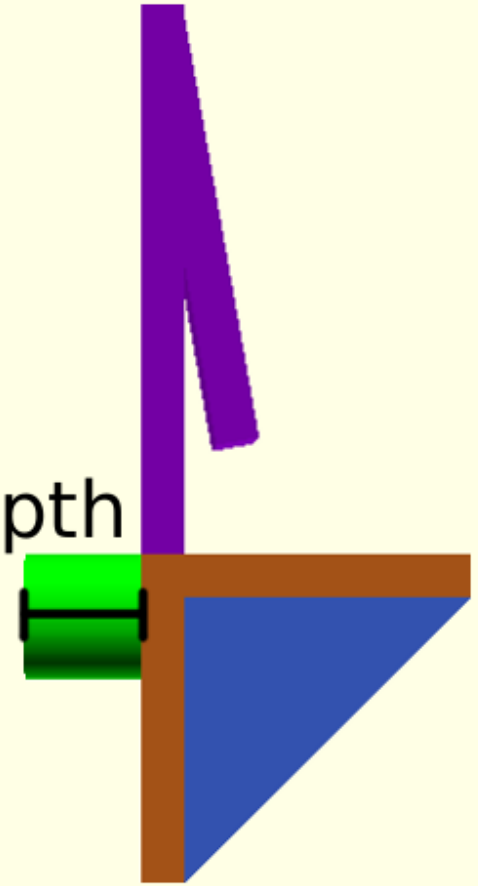
- Constants
- cylinder();
- center = false
- Modules
- Passing parameters

BACK



peg_diameter

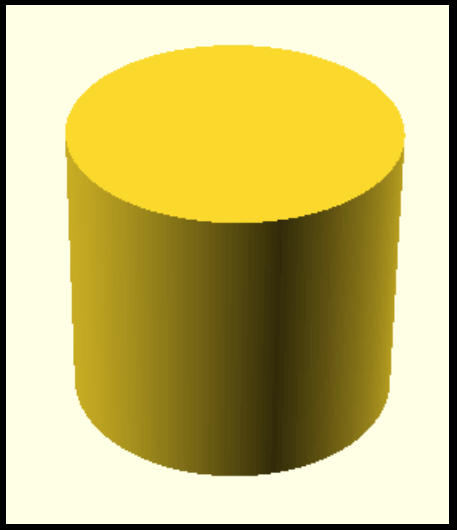
SIDE



peg_depth

Assignment 1

- Create a cylinder() with these constraints:
  - peg_diameter = 6
  - peg_depth = 5.5
- Create a peg() module to contain your cylinder

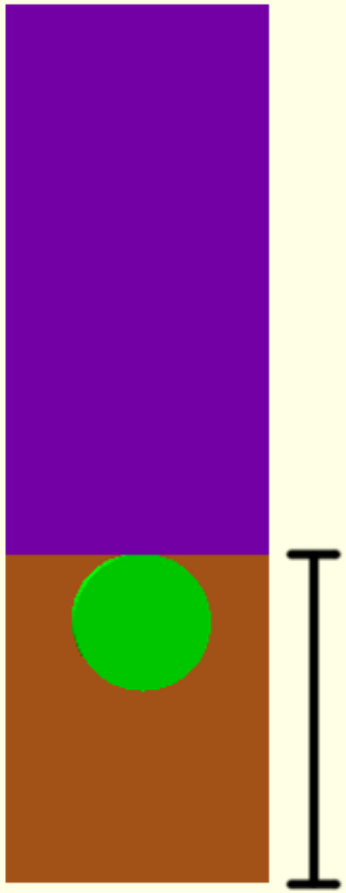


Training 2

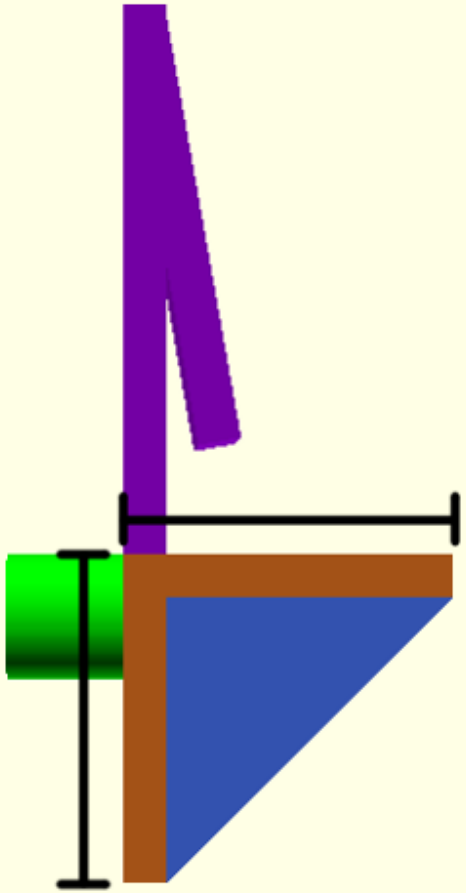
- Vectors
- Translate();
- Debugging tools
  - echo();
  - #function()
  - !function()
  - %function()

BACK

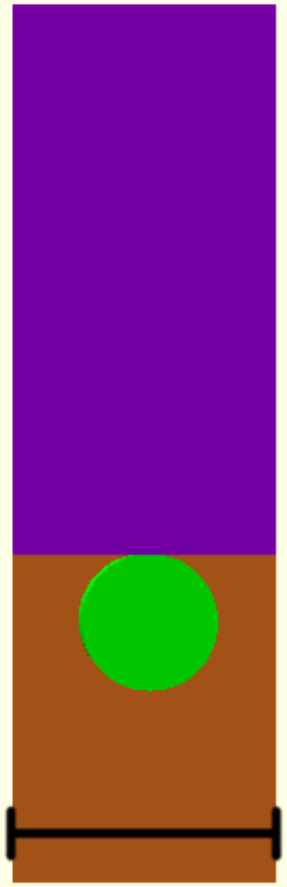
SIDE



Length

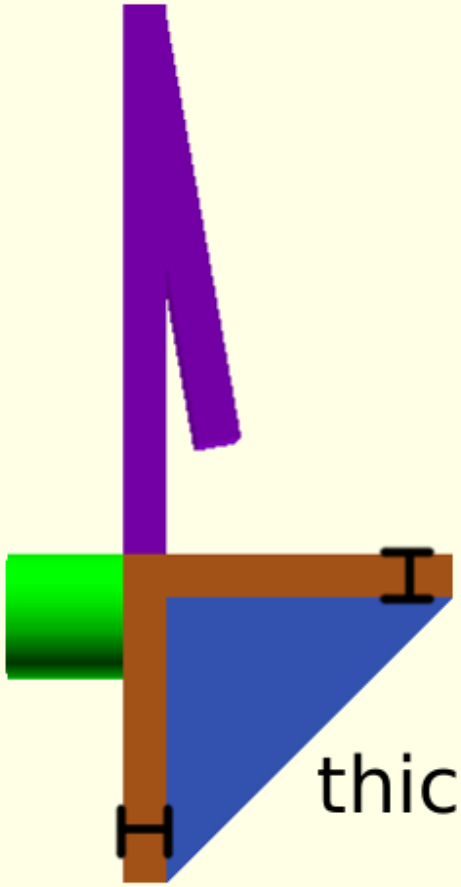


BACK



width

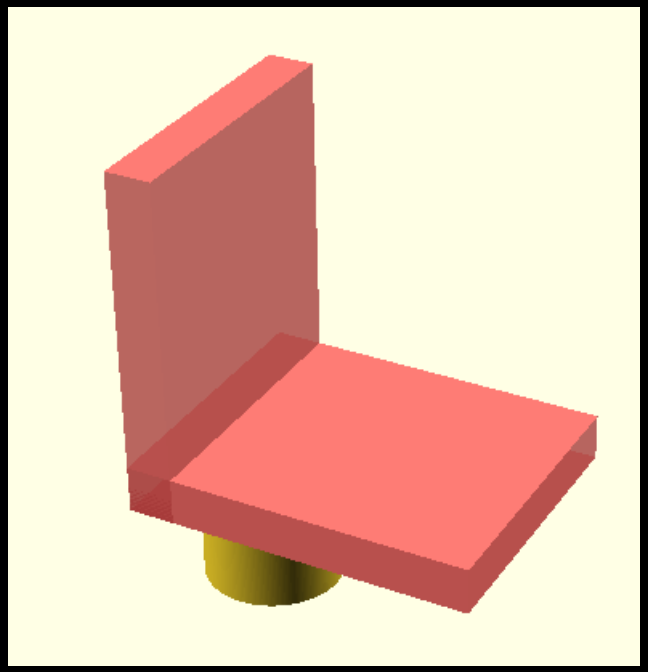
SIDE



thickness

Assignment 2

- Create a support() module with
  - Two cube()s at a 90° angle
  - length = 15
  - width = 12
  - thickness = 2



- Align peg() to the surface of support()
- Create a main() module to contain everything

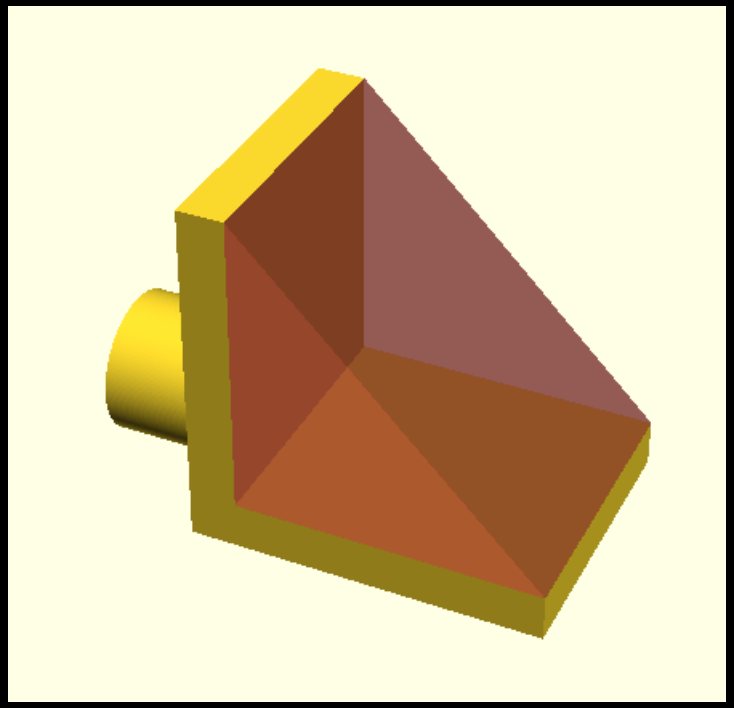
Robustness check

Training 3

- `difference();`
- `rotate();`
- `Additional uses of Vectors`
- `Nesting transformations or modules`

Assignment 3

- Create a brace() module
- Re-use parameters length, width, & thickness



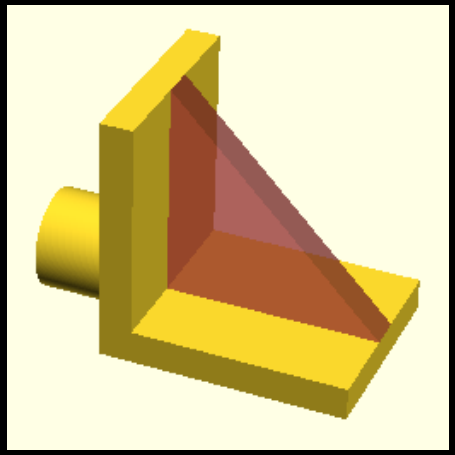
Robustness check

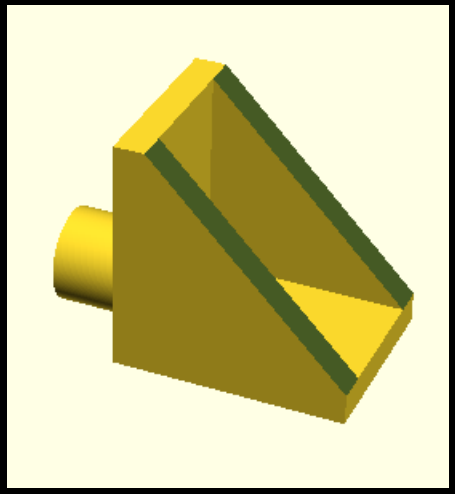
Training 4

- Conditions
- if() / else if() / else()
- Reusing modules

Assignment 4

- Create a new brace style “single”
  - Width should be equal to the constant “thickness”
- Create a new brace style “double”
  - Re-use and reposition two “single” styles braces
- Swap between all 3 styles by changing one constant





Robustness check

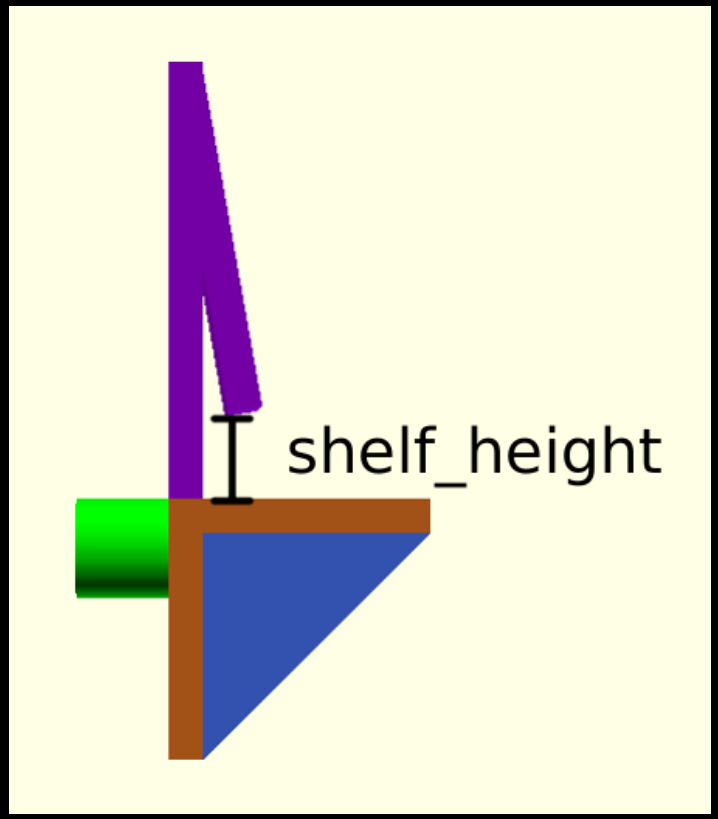
Training 5

- Trigonometric functions
  - sin()
  - cos()
  - tan()

Flashbacks to highschool geometry anyone?

Assignment 5

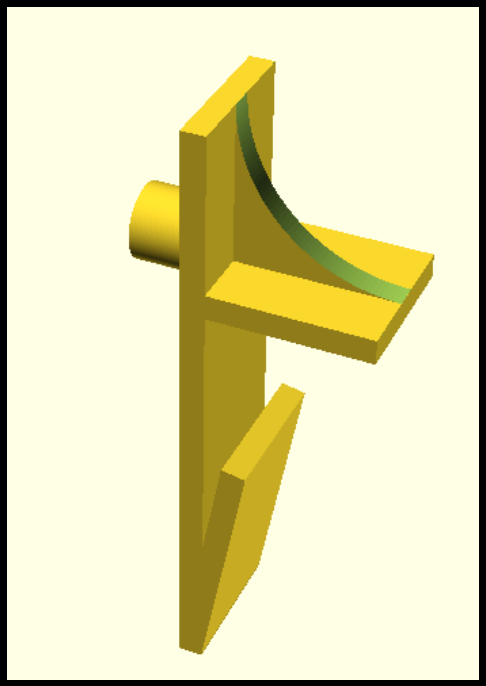
- Create a catch() module
  - shelf_height = 13.5
  - angle = 10°

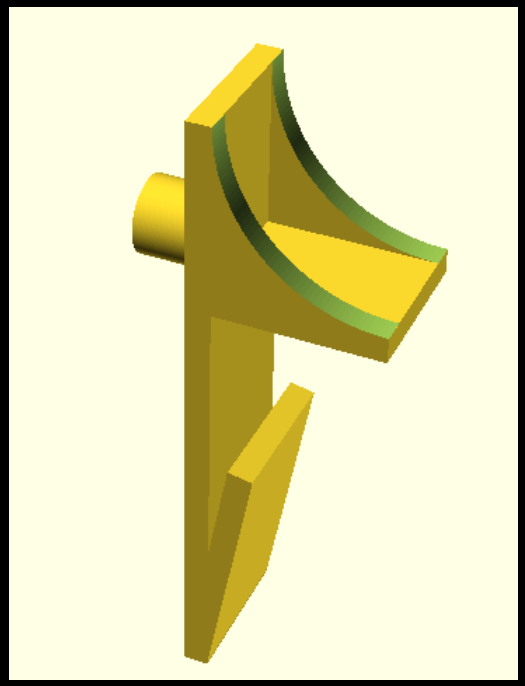


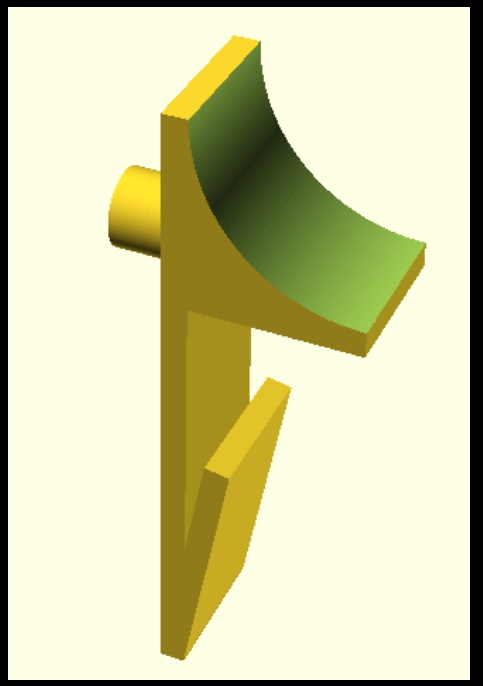
Robustness check

Assignment 6

- Modify brace() to cope with another shape
- Swap between shapes by changing one constant
- Play well with all 3 brace styles







Conclusion

- Outline
  - Intro to RE
  - Tools
  - OpenSCAD
  - Shelf bracket

- Twitter: @nickthetait
- Website: https://about.me/nickthetait

Resources

- “Hacking the Xbox: An Introduction to Reverse Engineering” by Andrew ‘bunnie’ Huang
  - Free download at https://www.nostarch.com/xboxfree
  - Read chapter 12 “Caveat Hacker”
- “Practical Malware Analysis” by Michael Sikorski and Andrew Honig https://nostarch.com/malware
- Contact Electronic Frontier Foundation for help finding an attorney https://www.eff.org/about/contact

Images



- Any images not listed below are my own work

- Slide # - Description – source
- (nearly every slide) – High quality Emojis - https://www.deviantart.com/dabolus/art/Complete-Emoji-Collection-555211222
- 4 - Malware book - https://nostarch.com/malware
- 12 - RE definition - https://www.merriam-webster.com/dictionary/reverse%20engineer
- 19 - Game controller - https://twitter.com/calebkraft/status/772471226694369280
- 22 - RE as a Service – https://reverseengineeringservice.com
- 29 - White 3D printer – Ultimaker S5 image from https://ultimaker.com/en/press-room
- 29 - Black/Green 3D printer – LulzBot Mini 2 image from https://www.lulzbot.com/learn/announcements/introducing-lulzbot-mini-2
- 36, 37 – contract production - www.3dhubs.com