PL Techniques for 3D Printing

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PLSE

Compilers generate
our environment.







TROPICLAND


TROPICLAND


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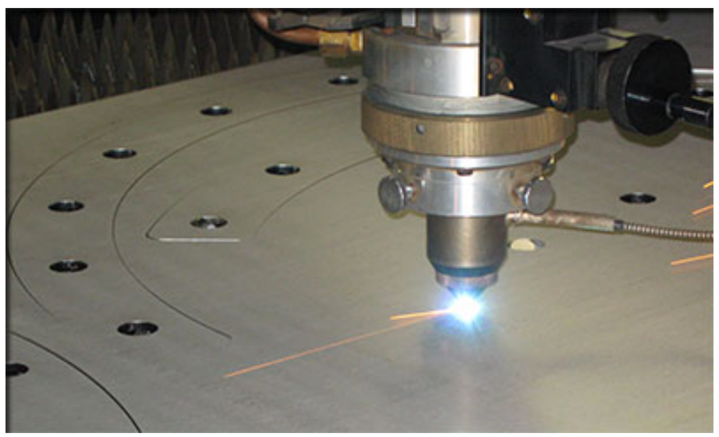
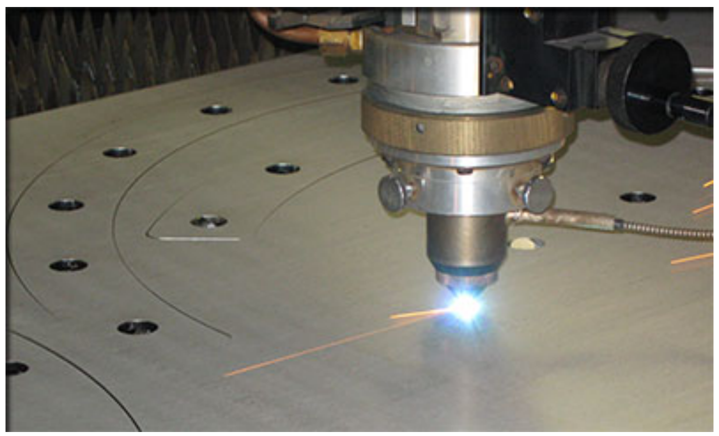
Computerized Manufacturing



CNC

Computerized Manufacturing



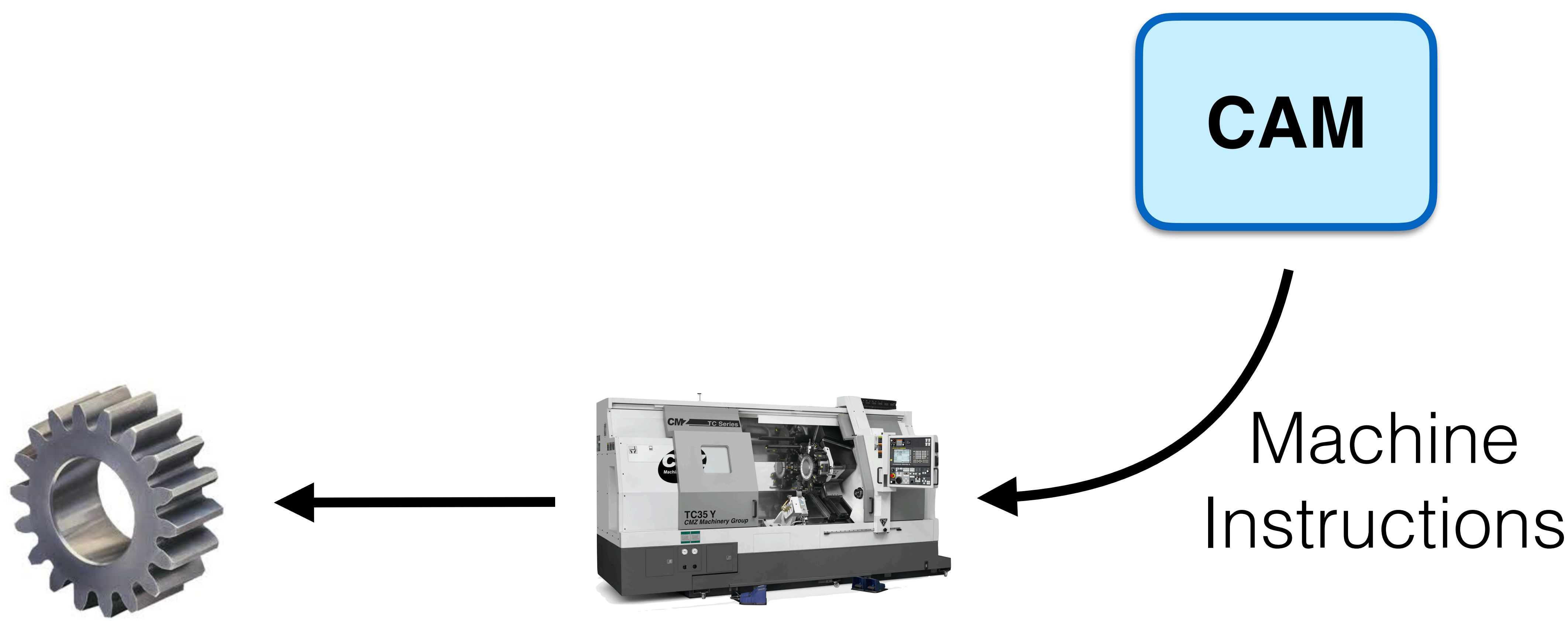
CNC

Mold Making

Robotic Assembly

Computerized Manufacturing

Computerized Manufacturing



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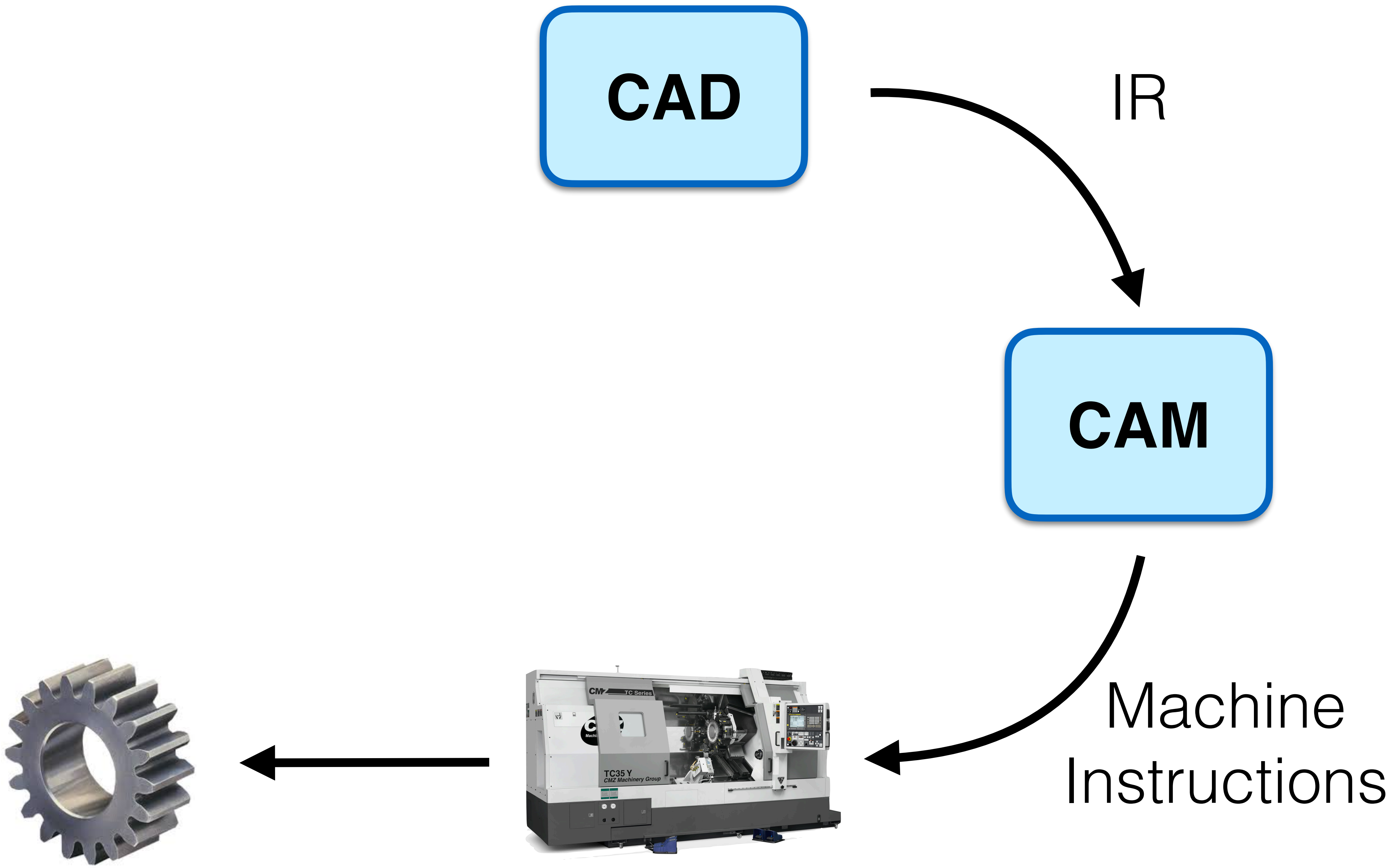

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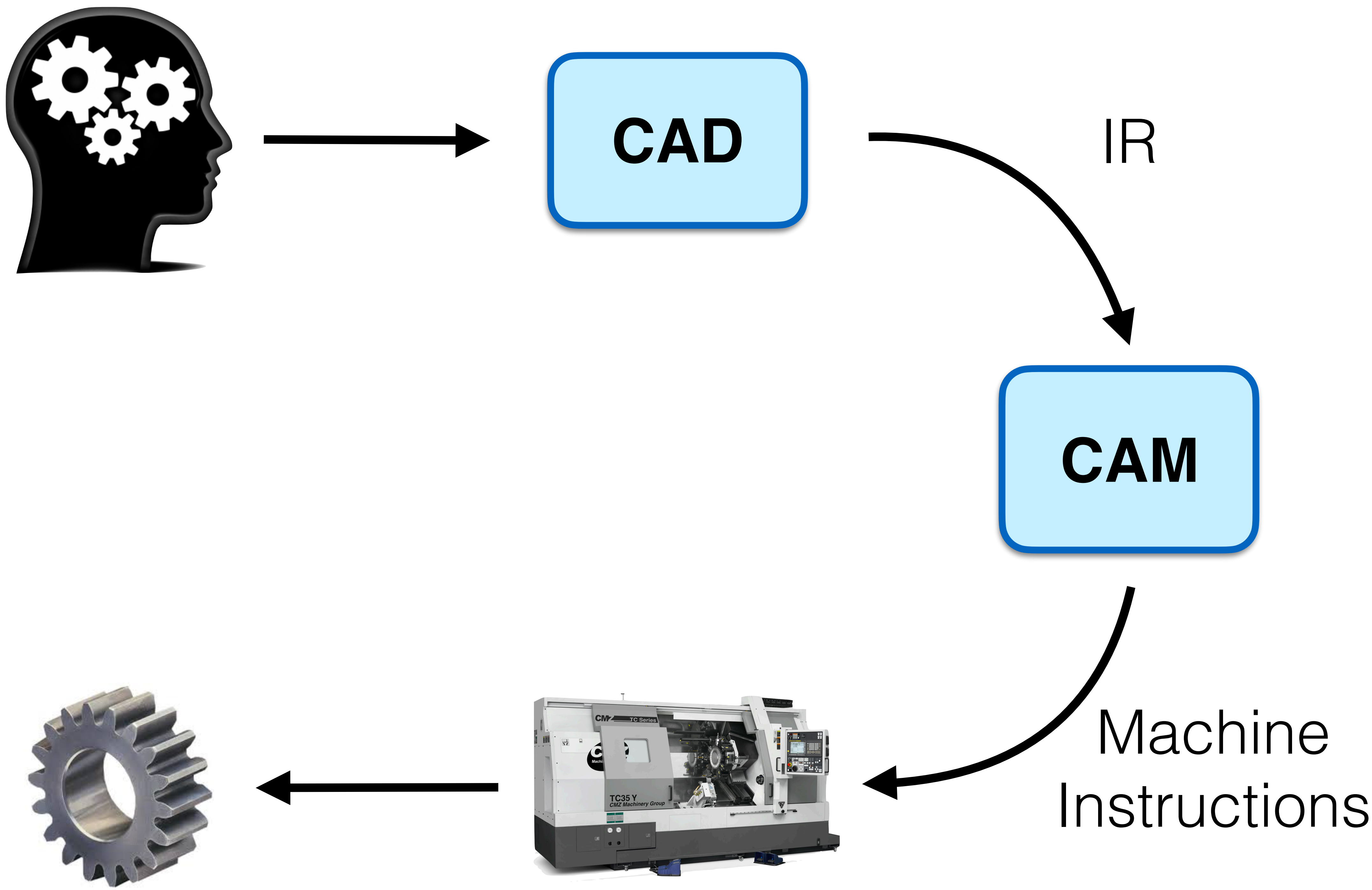
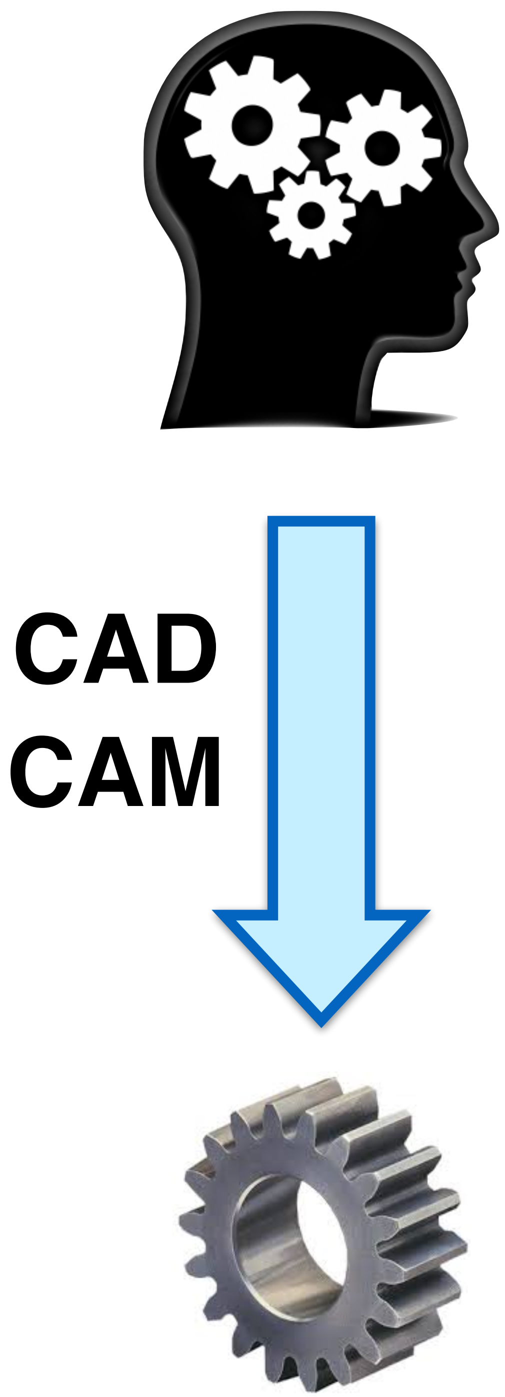


CAD/CAM : Idea → Part



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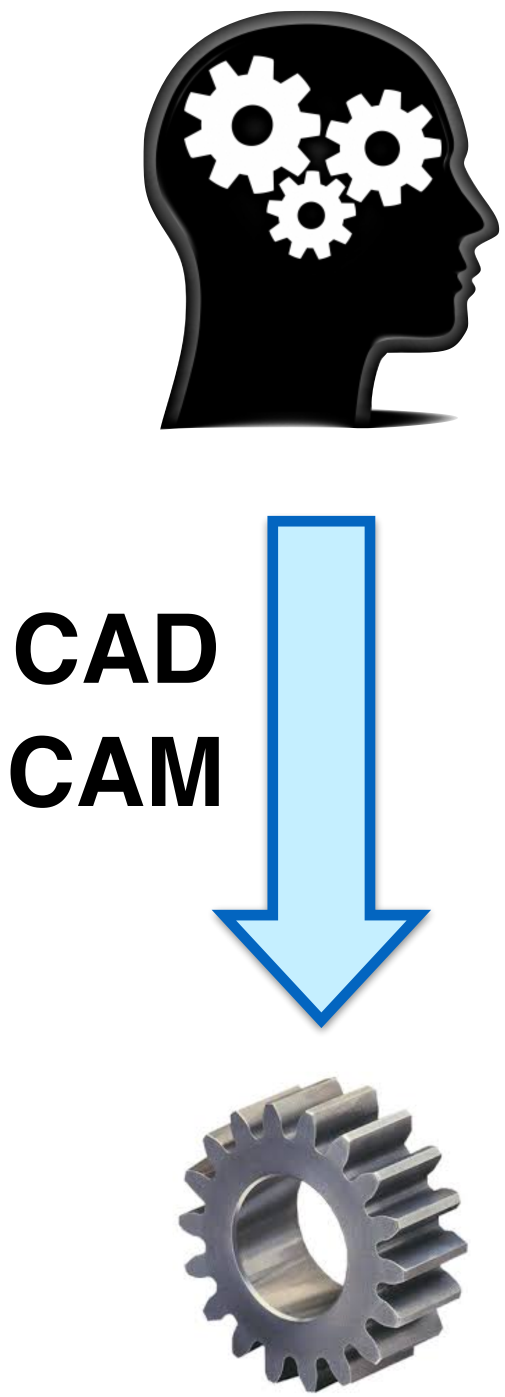

Where is the PL theory?

- semantics
- equivalence
- refinement
- approximation

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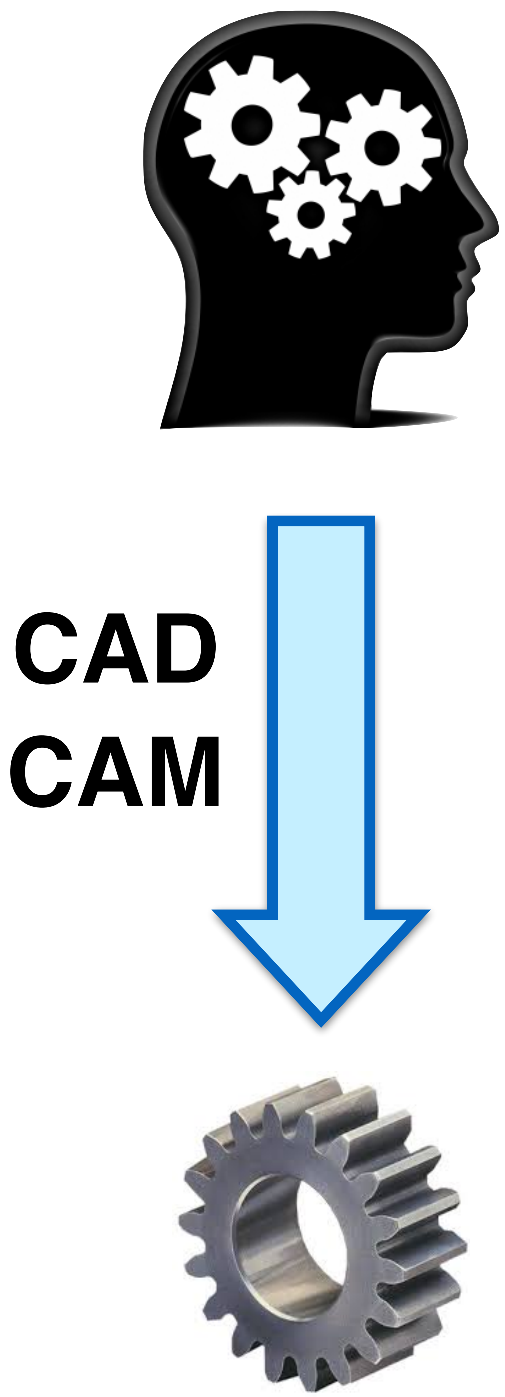

Where is the PL theory?

- semantics
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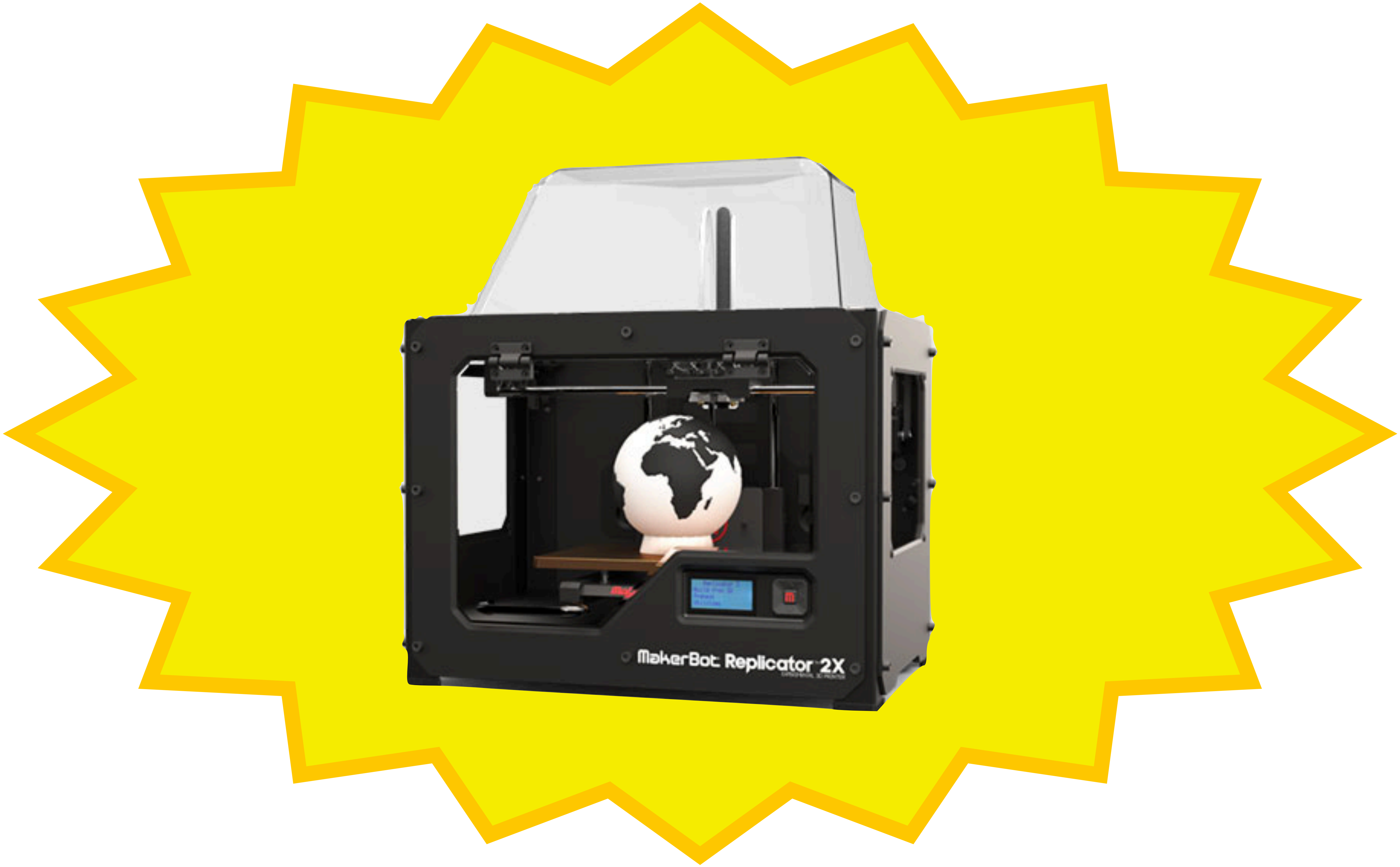
- approximation

Already worthy challenge, but recently…

Democratized Manufacturing



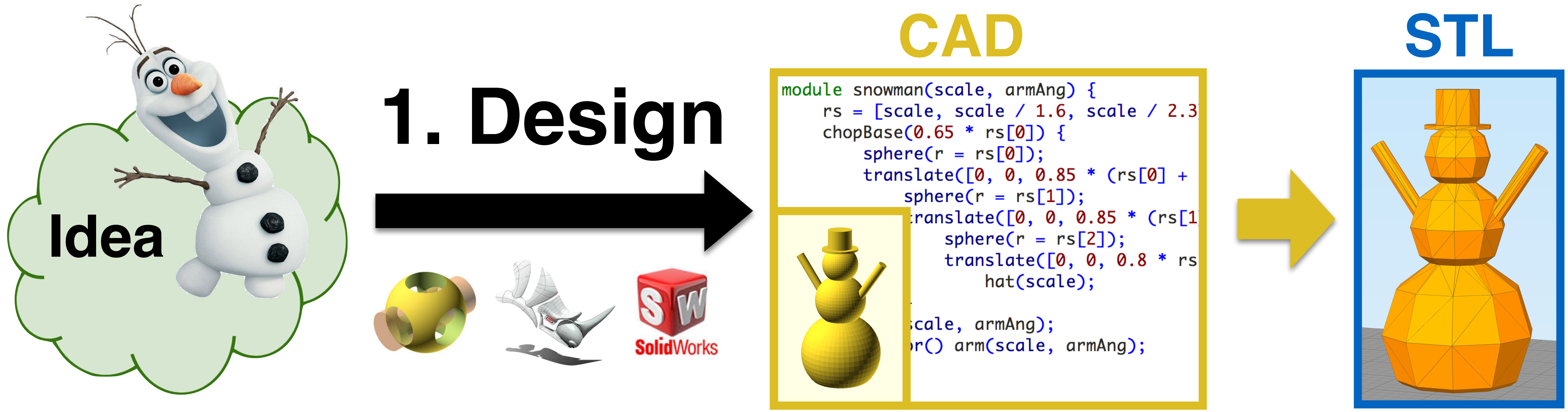
3DP: PL Opportunity

3D Printing Background

Challenge: CAD Synthesis

Challenge: Slicing Framework

3D Printing Workflow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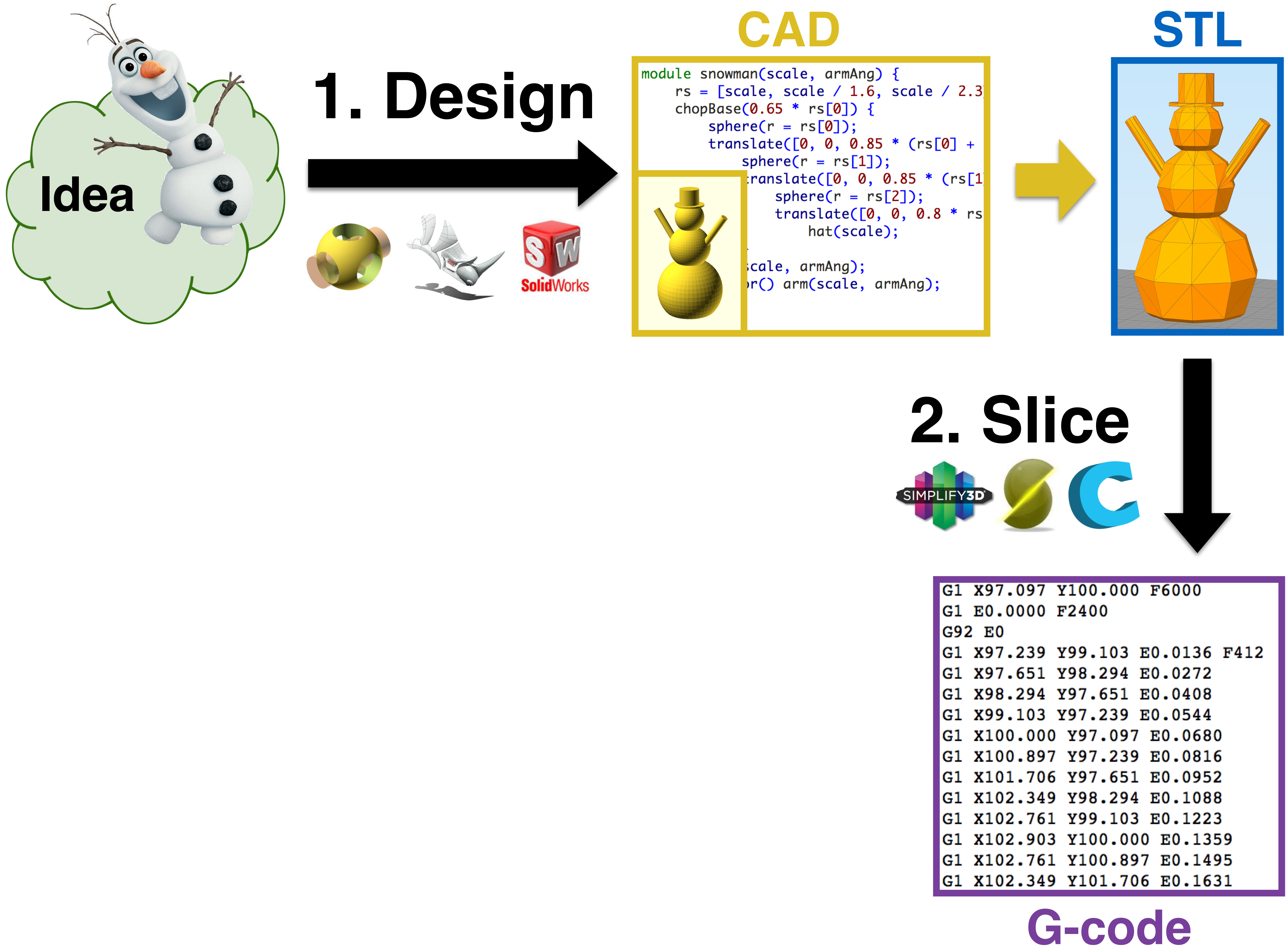
STL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G1 X97.097 Y100.000 F6000
G1 E0.0000 F2400
G92 E0
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G1 X97.651 Y98.294 E0.0272
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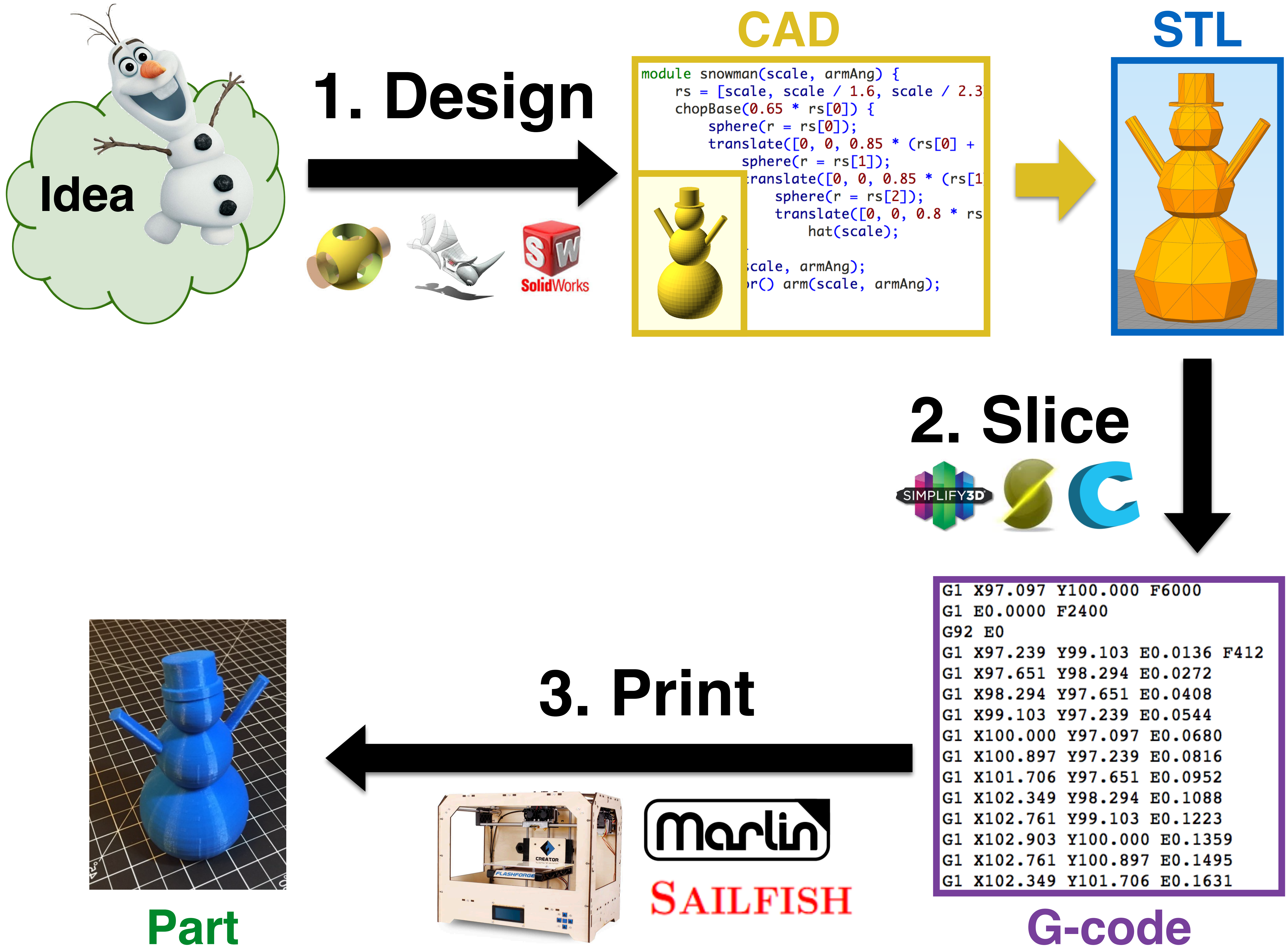
G-code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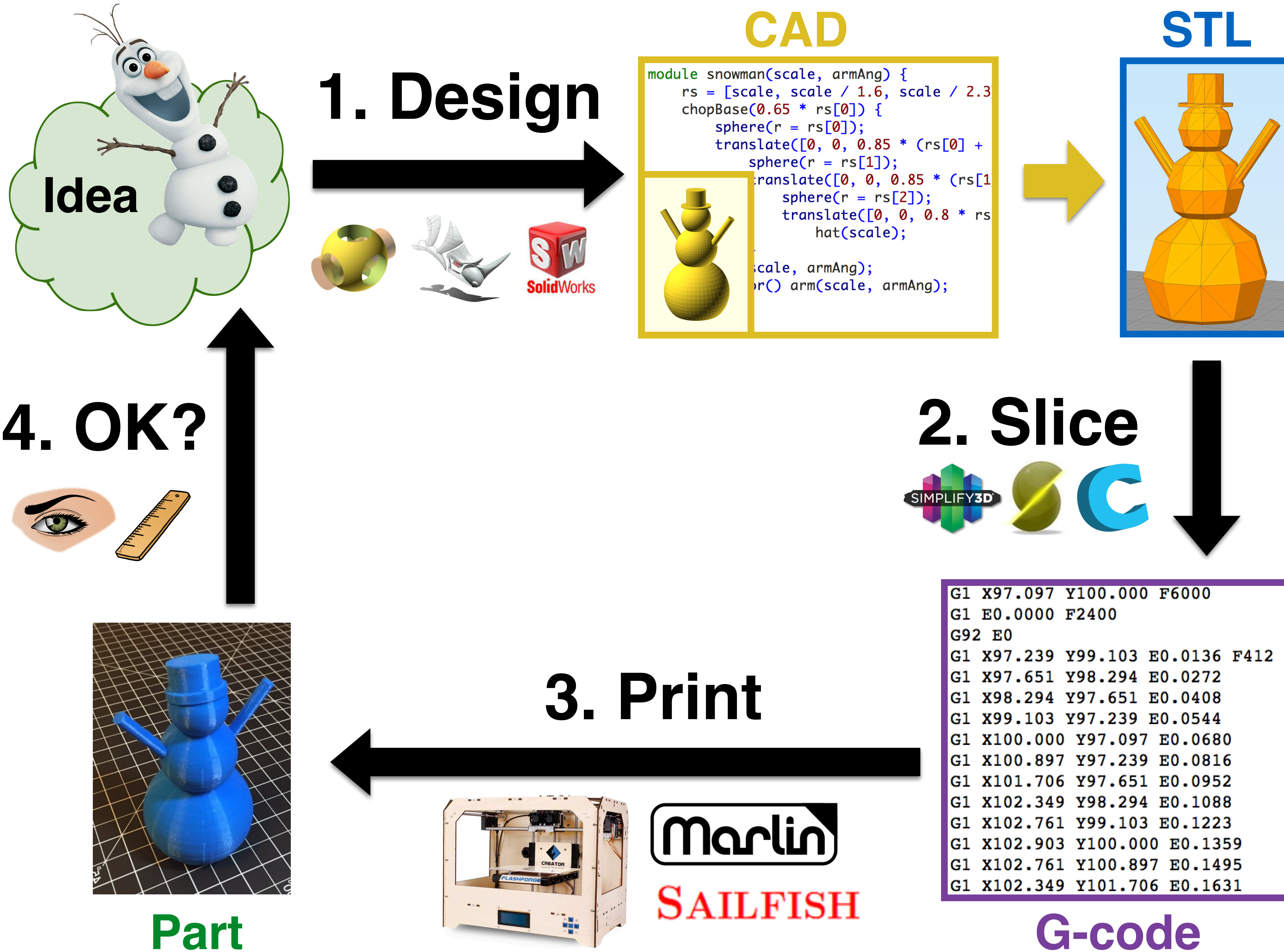
G-code
3. Print
Marlin
SAILFISH
Part



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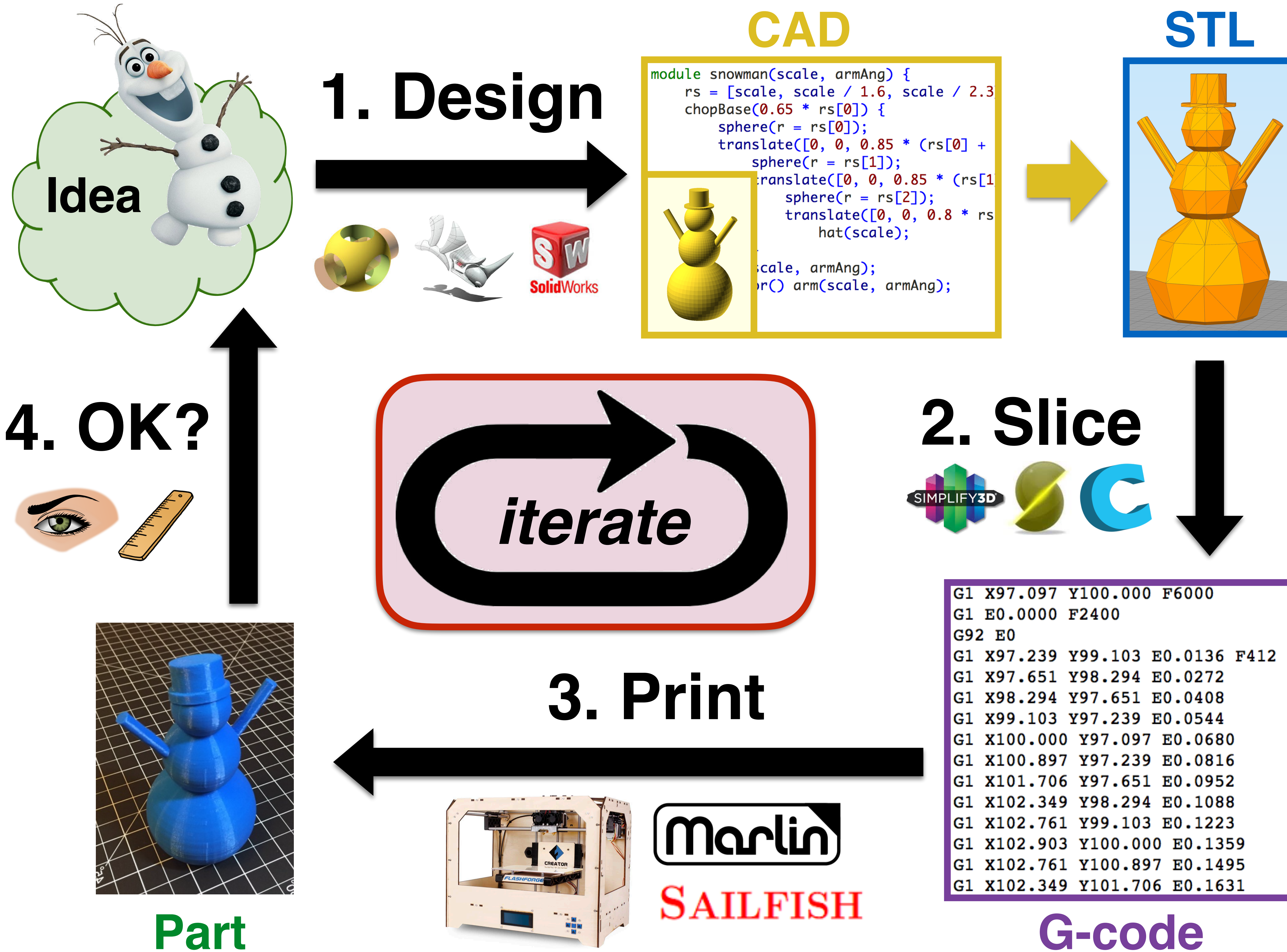
4. OK?



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3DP: PL Opportunity

3D Printing Background

Challenge: CAD Synthesis

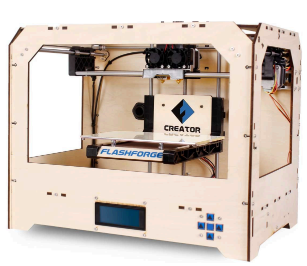
Challenge: Slicing Framework

Challenge: CAD Synthesis

: `CAD → STL`

SIMPLIFY3D

: `STL → G-code`



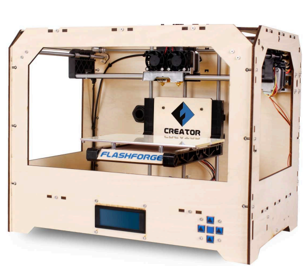
: `G-code → Part`

Challenge: CAD Synthesis

??? : `Idea → CAD`

: `CAD → STL`

: `STL → G-code`



: `G-code → Part`

Today: Crowdsource Designs

Thingiverse

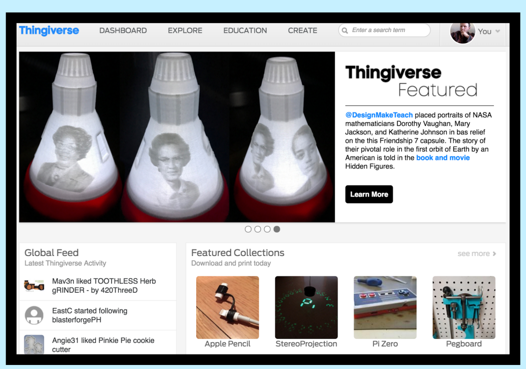
YM GRABCAD

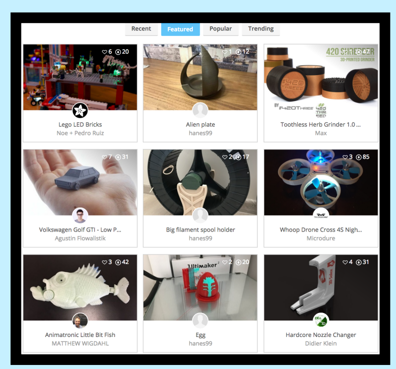
: Internet → Idea → STL

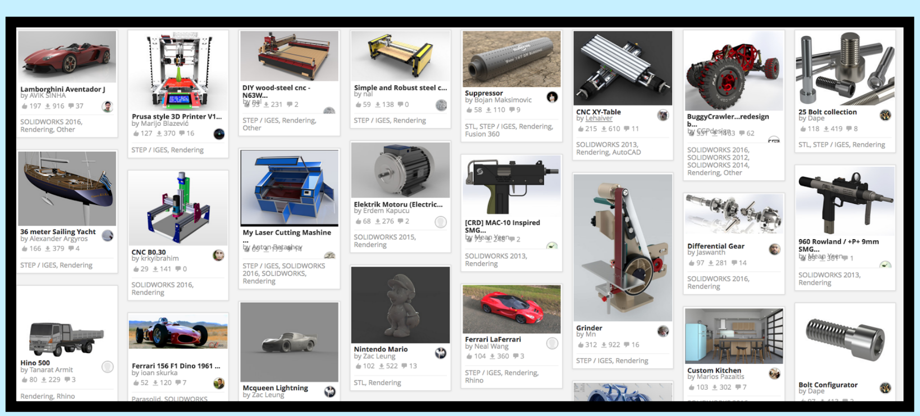
Today: Crowdsource Designs

Thingiverse : Internet → Idea → STL

YM GRABCAD



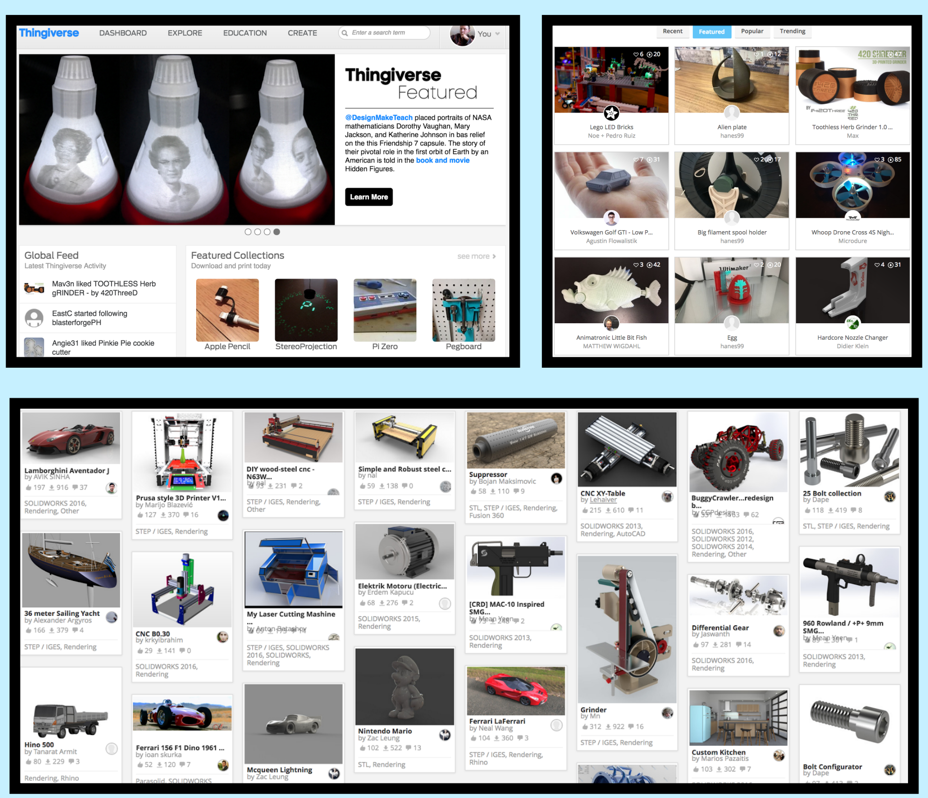




+ Easy

Today: Crowdsource Designs

Thingiverse / YM GRABCAD : Internet → Idea → option STL



+ Easy

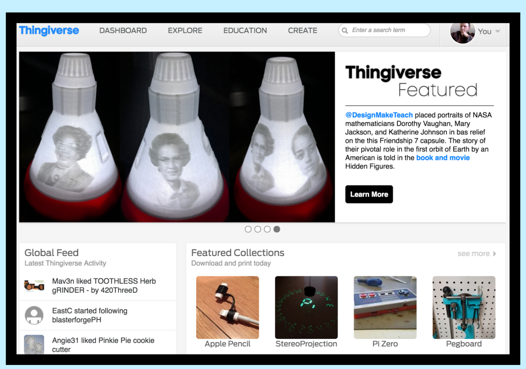
- Incomplete

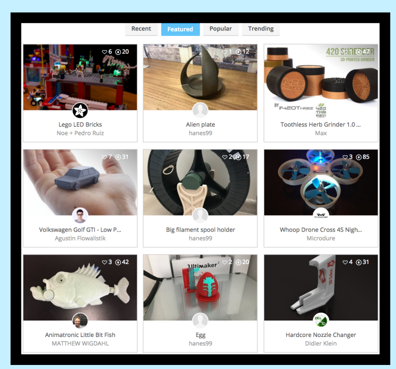
Today: Crowdsource Designs

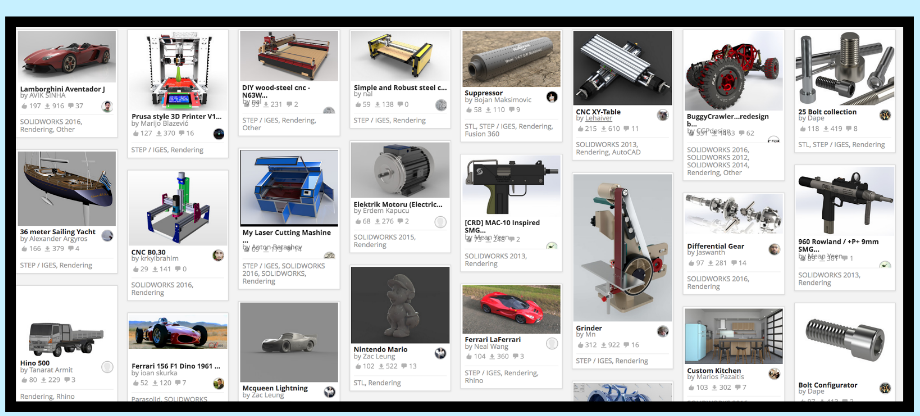
Thingiverse

YM GRABCAD

: Internet → Idea → option STL







+ Easy

- Incomplete

- Hard to modify

Today: Crowdsource Designs

Thingiverse
YM GRABCAD : `Internet → Idea → option STL`

Goal

For idea **`i`**, even when:

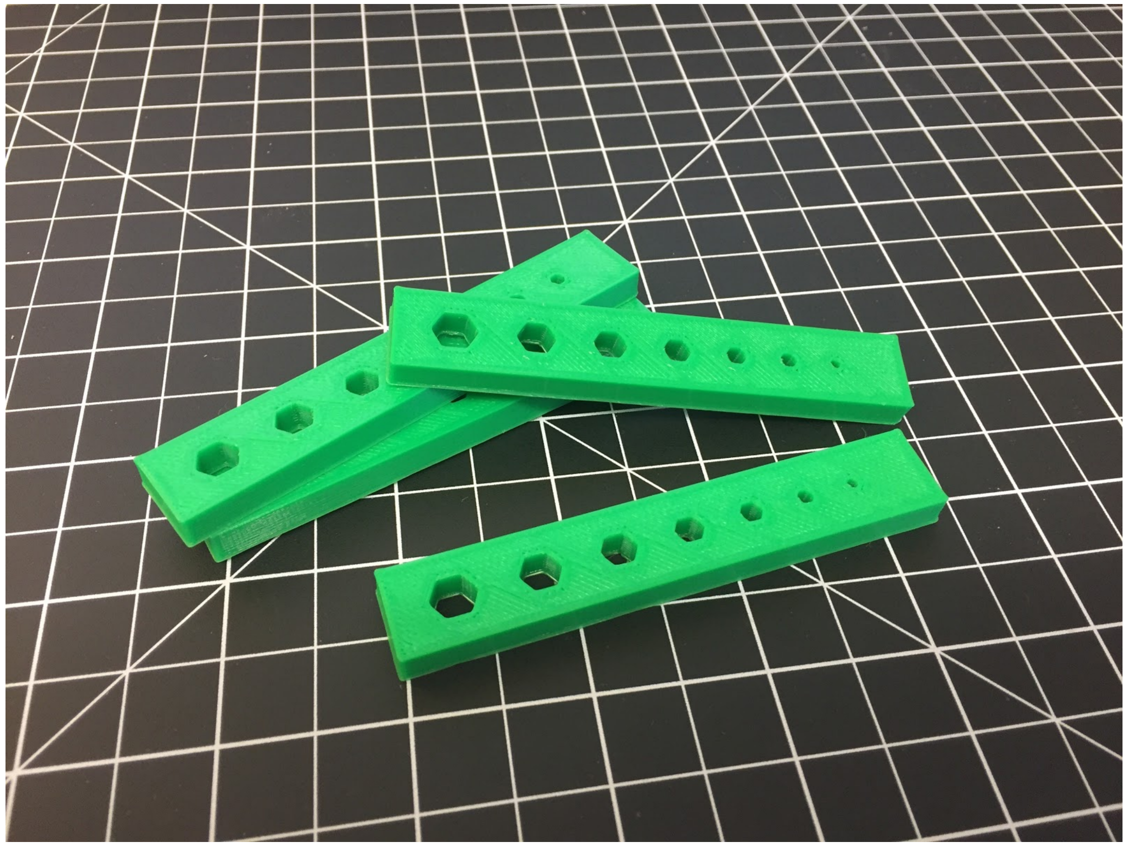
Thingiverse (☁ , `i`) = **`None`**

there often exists similar **`i'`** such that:

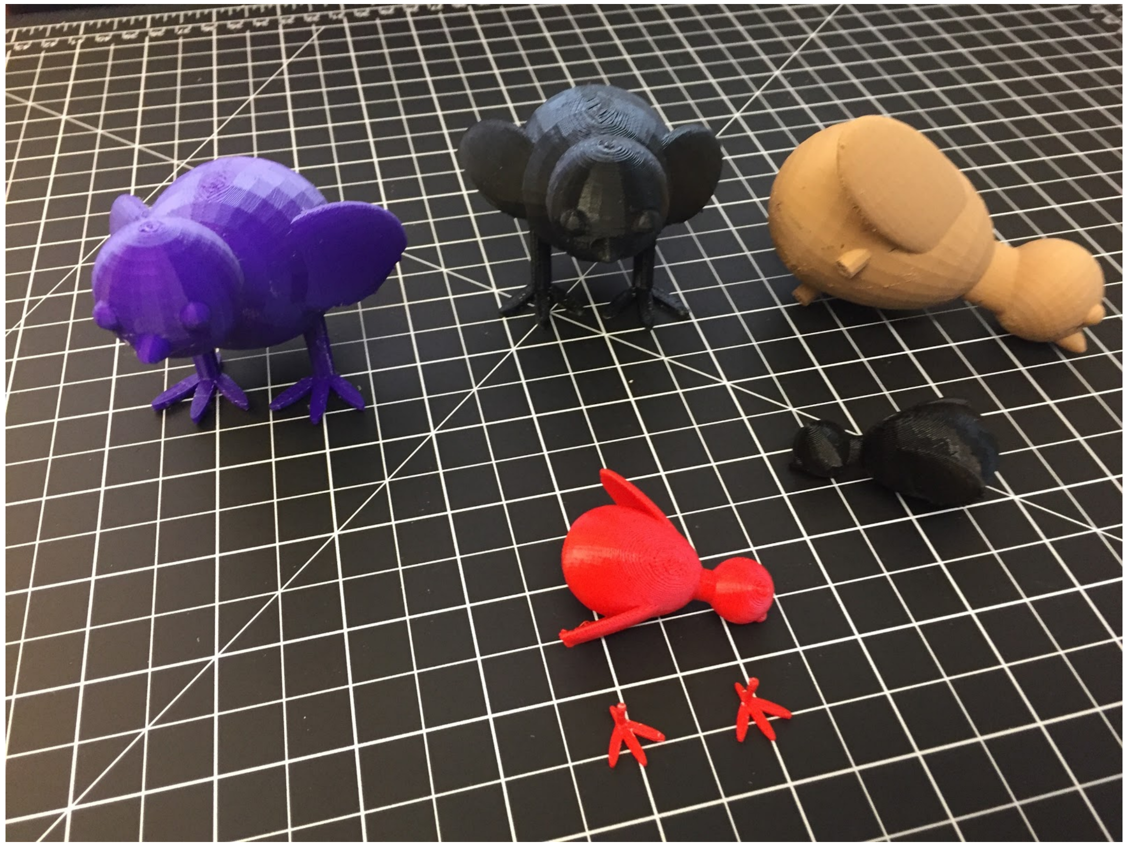
Thingiverse (☁ , `i'`) = **`Some s`**

So: adapt "almost" design **`s`** to a design for **`i`**!

Example "Almost" Designs

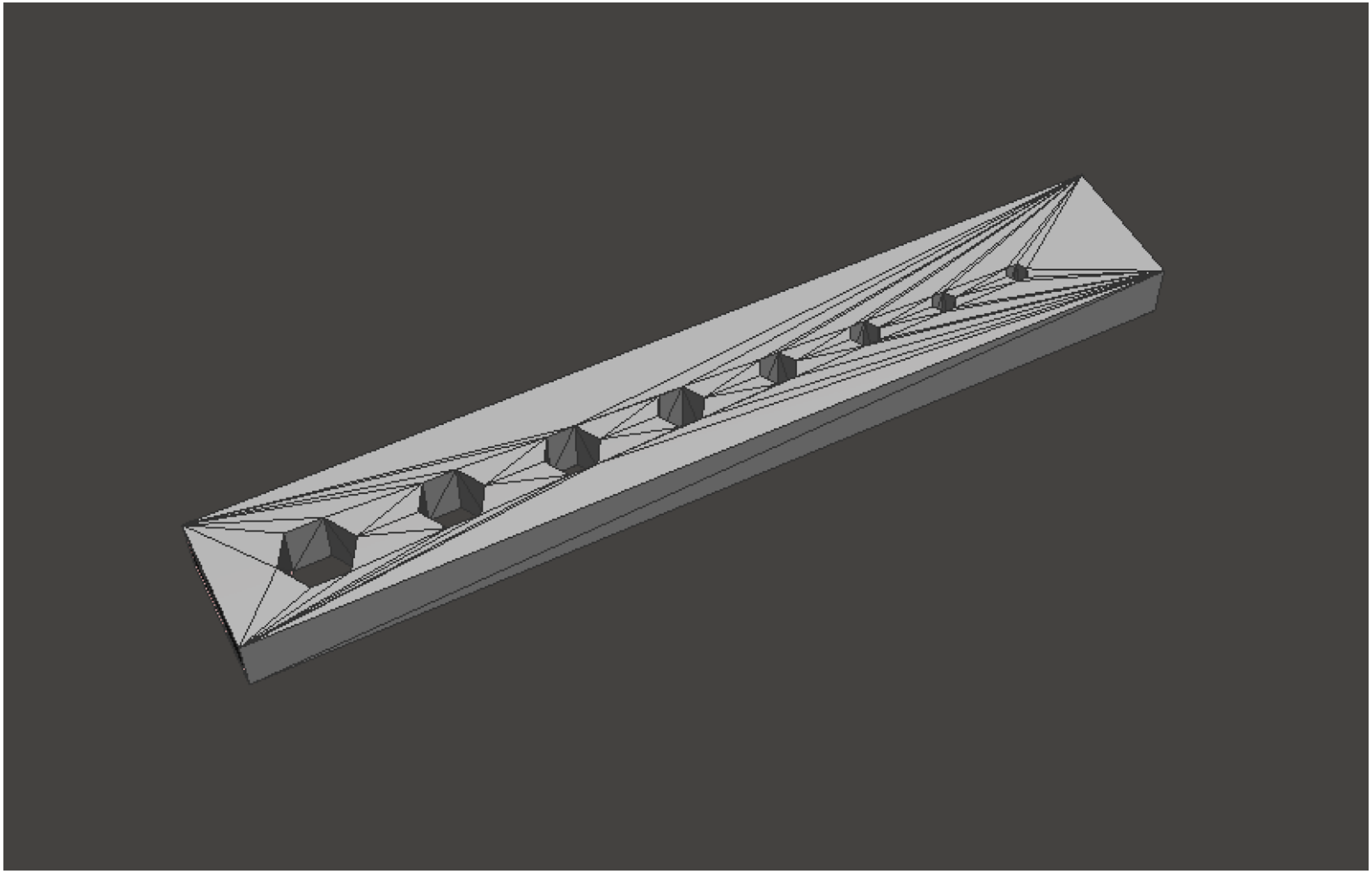


Rotated Hex Hole



Broken Chicken Legs

Inferring CAD to fix hex holder



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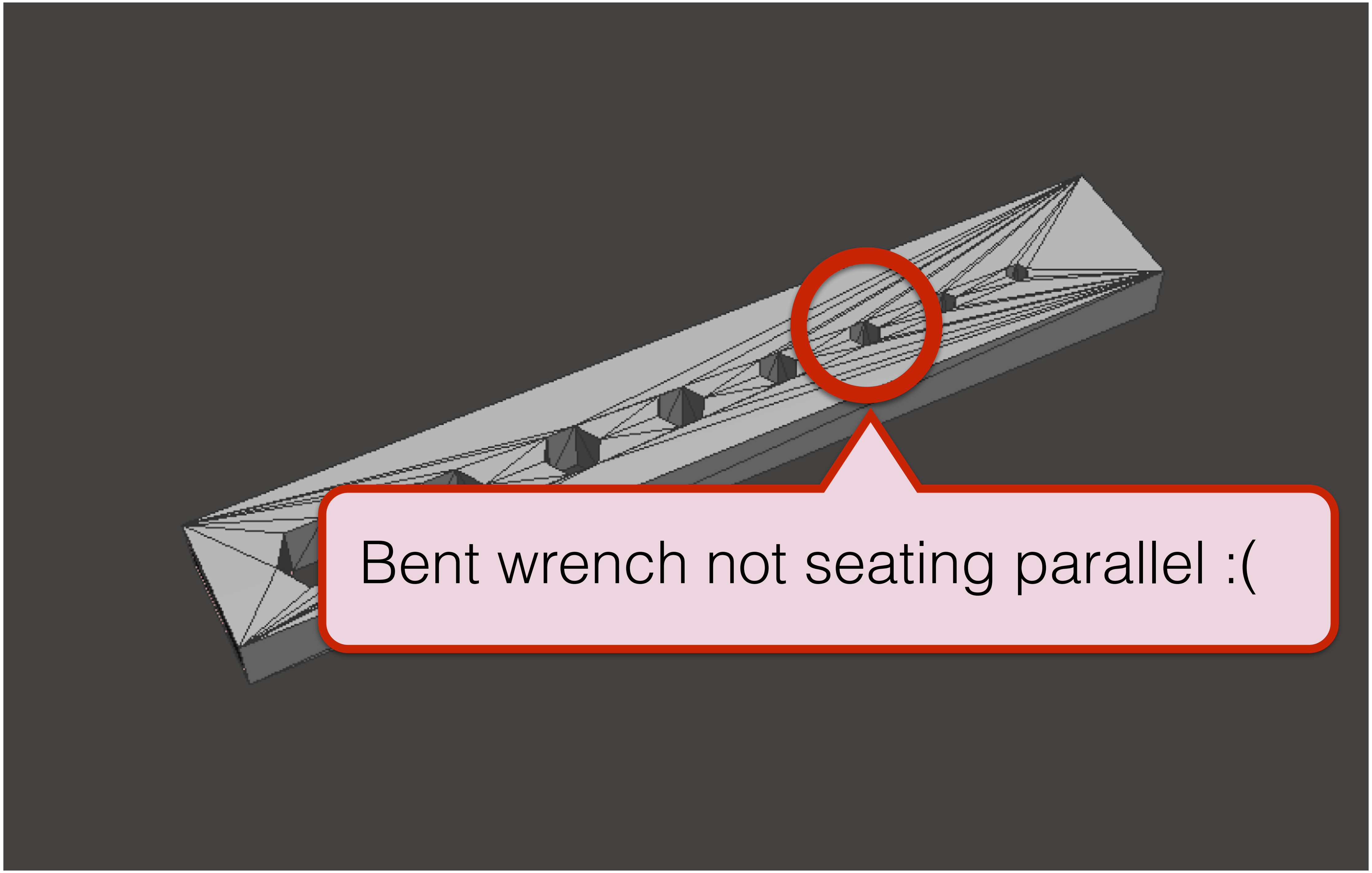

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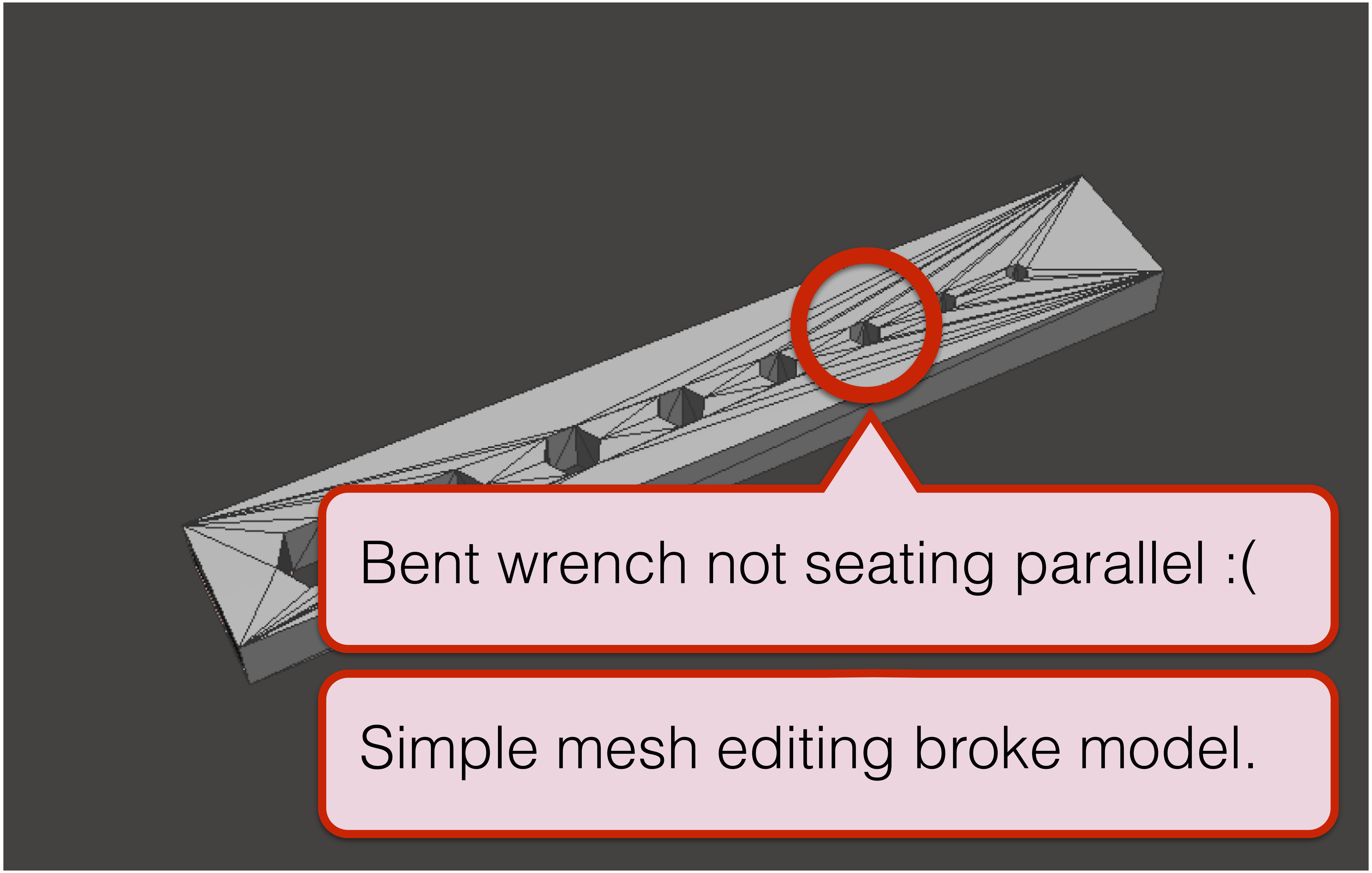

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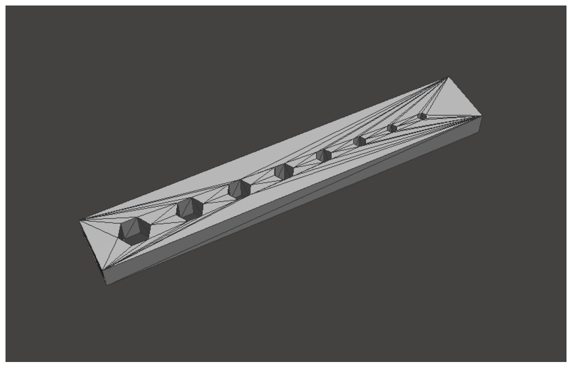

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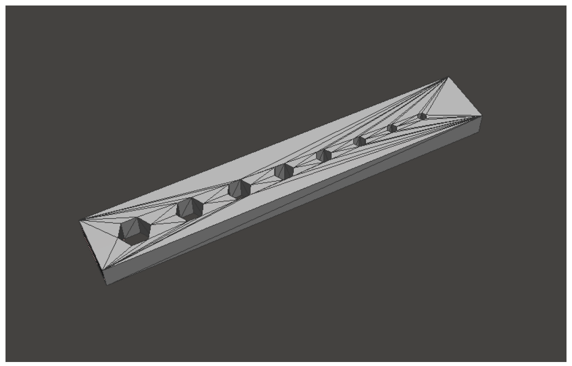
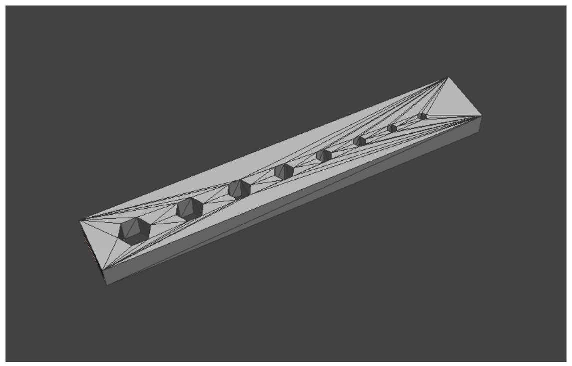


Infer

(manual)

```
difference() {
    cube([w, d, h]);
    for(i = [0 : len(holes) - 1])
        translate([offset(i), d/2, -1])
            hex_hole(holes[i]);
```

Inferring CAD to fix hex holder



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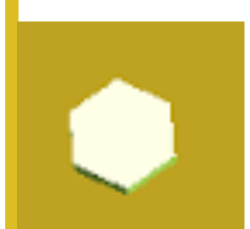
Tweak **(small)**

```
difference() {
    cube([w, d, h]);
    for(i = [0 : len(holes) - 1])
        tr
```

```
if(i == 5)
    rotate([0, 0, 35])
        hex_hole(holes[i]);
```

```
            hex_hole(holes[i]);
```



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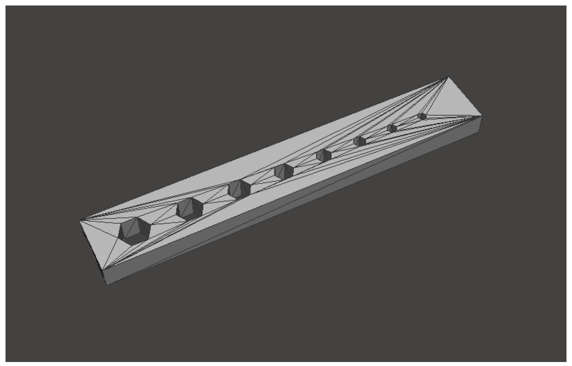

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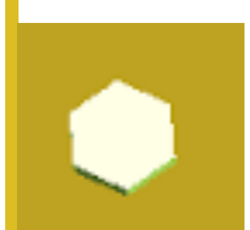
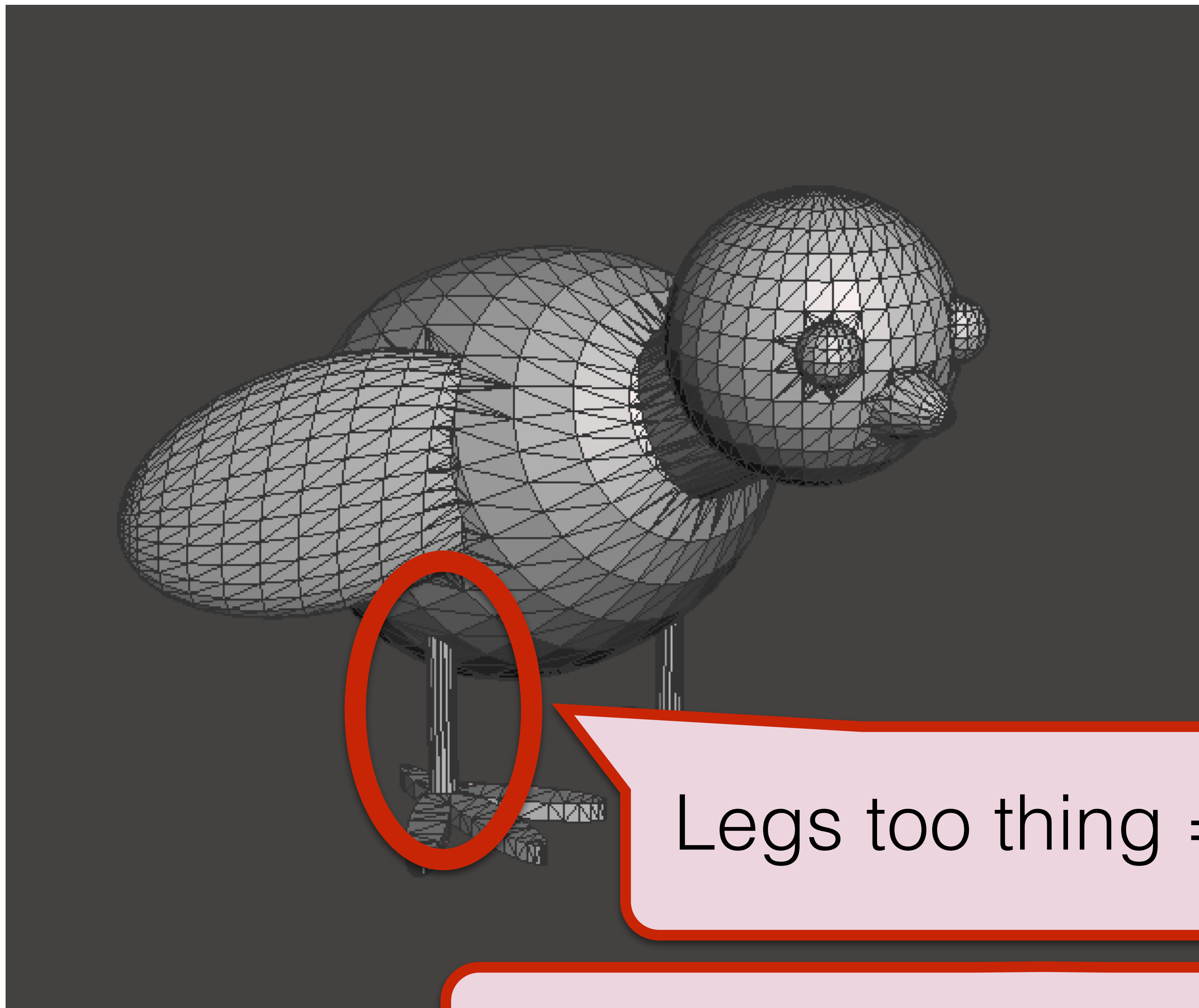


Print

(success)

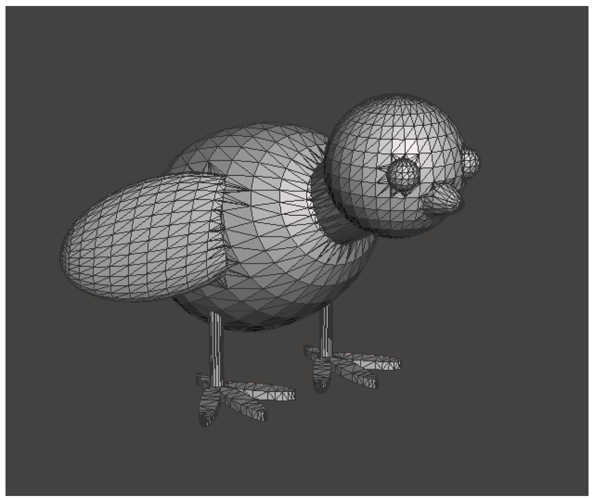
Inferring CAD to fix chicken



Legs too thing => broke!

Expanding leg in STL tedious.

Inferring CAD to fix chicken



Infer

(manual)

```
...
cylinder(h = 30, r = 2);
cylinder(h = 30, r = 2);
...
```

Tweak **(small)**

```
...
cylinder(h = 30, r = 4);
cylinder(h = 30, r = 4);
...
```

Print

(success)

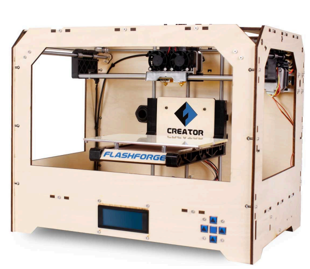
Challenge: CAD Synthesis

decompiler

∘ : Internet → Idea → CAD

: CAD → STL

: STL → G-code



: G-code → Part

3DP: PL Opportunity

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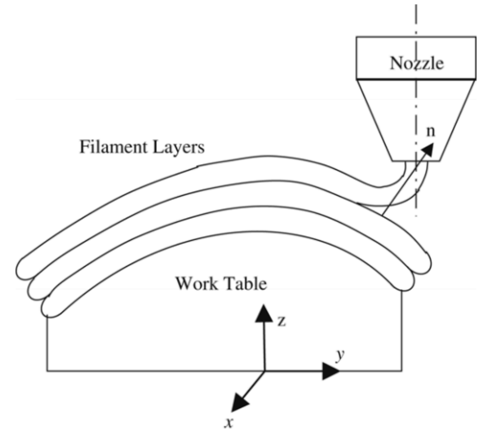
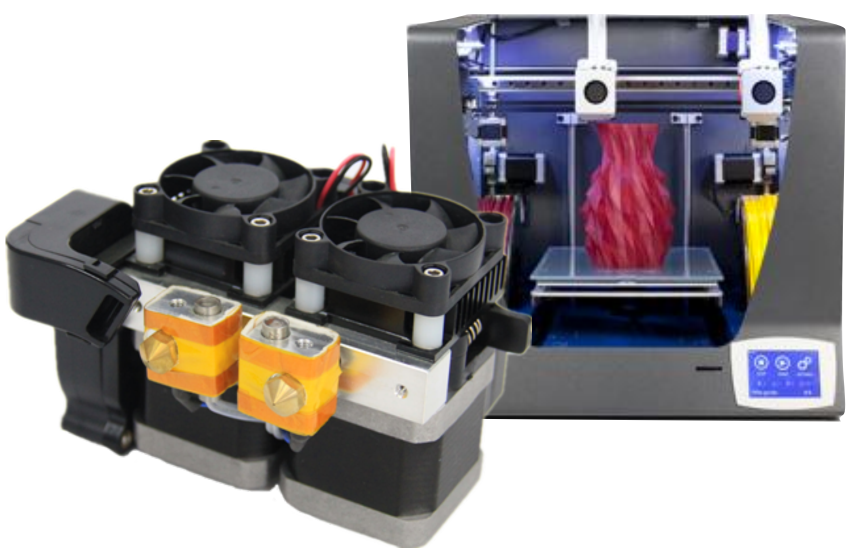
Exploring Slicing Strategies

Partitioning [Chopper 12]



Curved Layer FDM [CAD 08]



Parallelization

Multi-material [OpenFab 13]

Approx [Wireprint 14]

3DP Slicing Framework

Today: roll your own framework

Goal: LLVM / CIL for 3D Printing

Should enable exploring many new strategies:

- error compensation
- G-code synthesis with Z3
- parallelizing peepholes
- cross-part constraint
- …

3DP: PL Opportunity

Solid foundation:

- compiler theory
- fast solvers
- diverse synthesis
- num. methods

Goals:

- fab theory
- efficiency
- self-stabilize
- tools

Compilers generate
our environment.

Compilers generate
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PL folk can develop the
tools to make it better.

Thank You!

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