UNIVERSITY OF KENTUCKY

3D Printing

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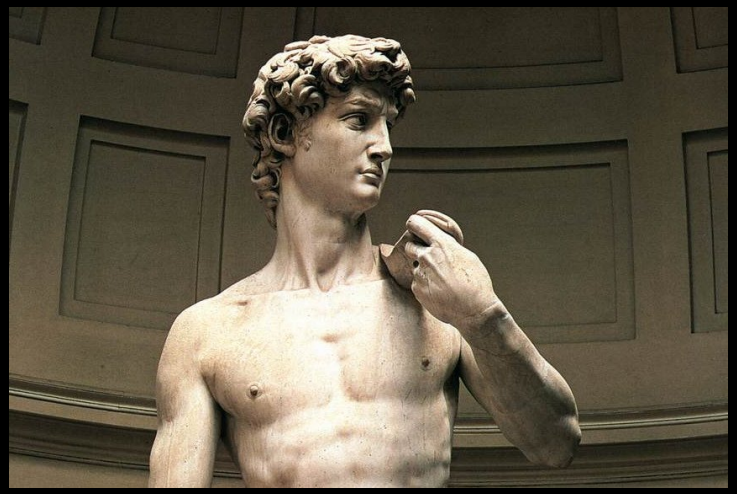
University of Kentucky
Electrical & Computer Engineering

Kentucky UNBRIDLED SPIRIT

How To Make Stuff

- People used to make things by hand...
  but humans make and use tools
- Most tools are special purpose;
  they only make a particular type of thing
- Using computer control we can build
  smart, generic, tools –
  even tools that can build themselves
  (RepRap: Replicating Rapid prototyper)

Subtractive Building



"Every block of stone has a statue inside it and it is the task of the sculptor to discover it."

– *Michelangelo*

Subtractive 2D

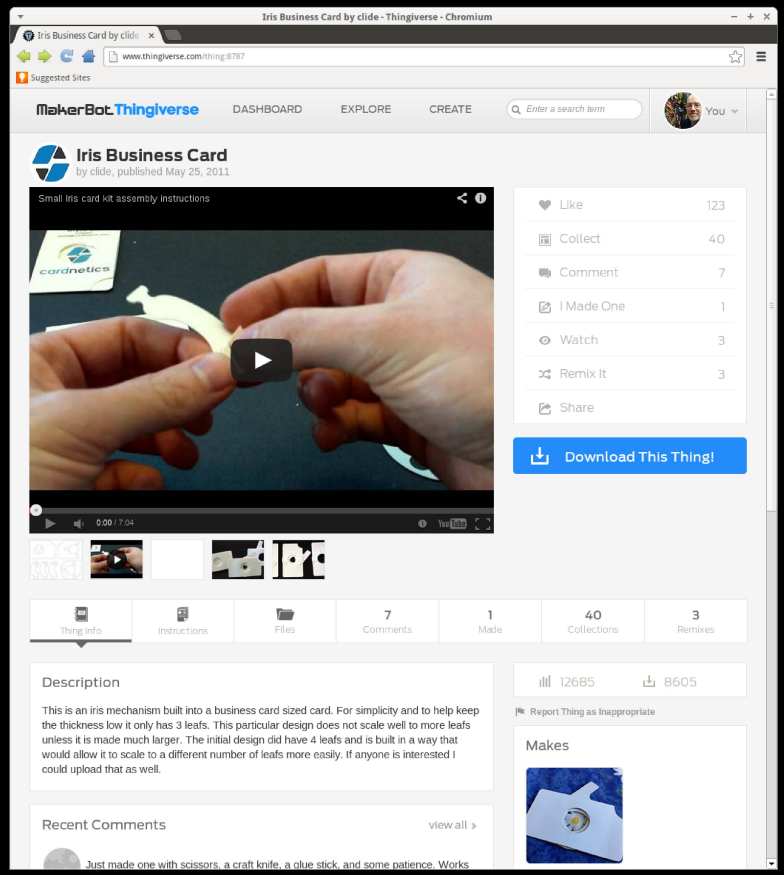
- Cutter: cuts 2D material in any pattern
- Paper/Craft: paper moves in Y, knife in X
- EDM/Laser: X/Y bed, vaporizes material

Subtractive 3D

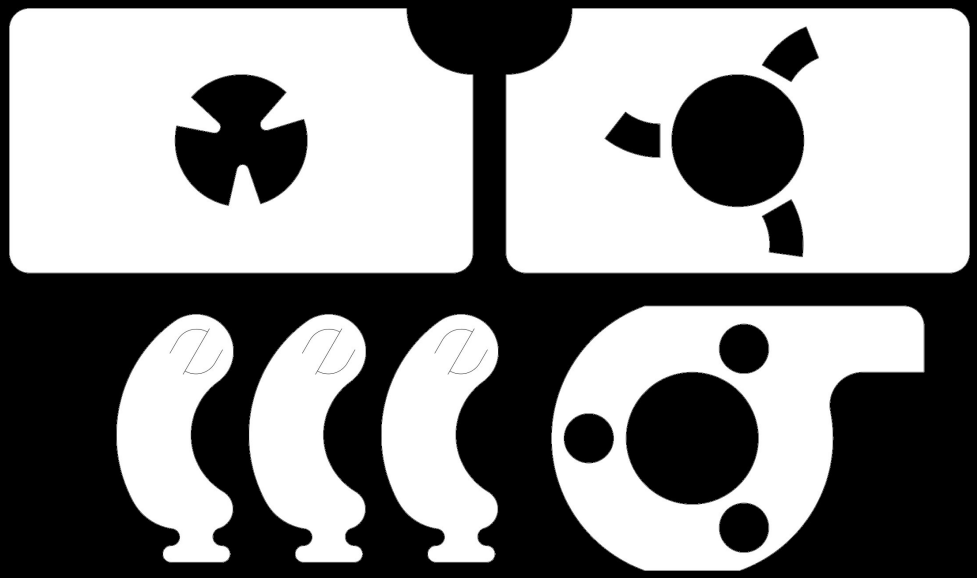
- CNC: Computer Numerical Control
- Mill/Router: part on X/Y bed, bit on Z axis
- Lathe: spins the part against a cutter

Making The Iris Card

- Subtractive 2D
- A working aperture iris made of card stock
- Design from Thingiverse: Thing 8787

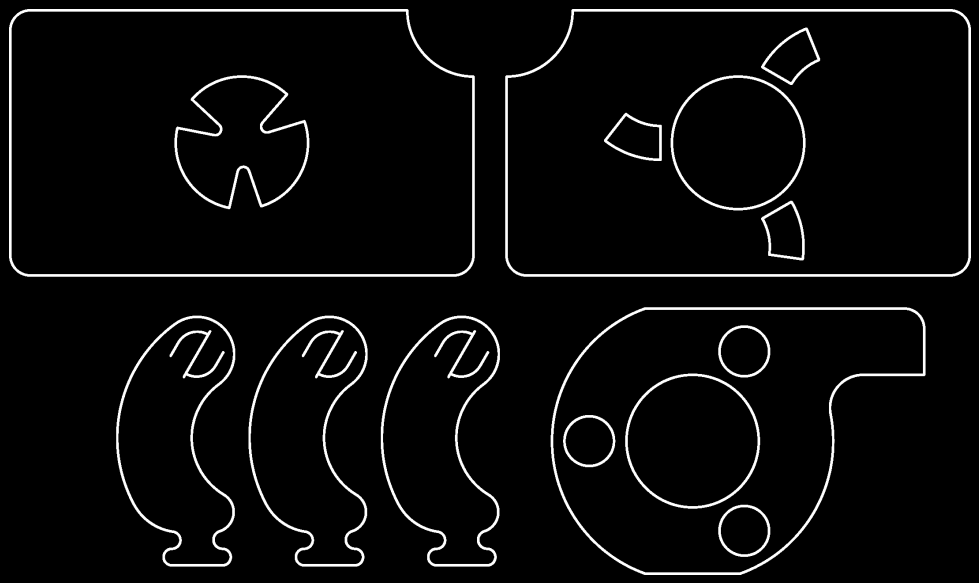


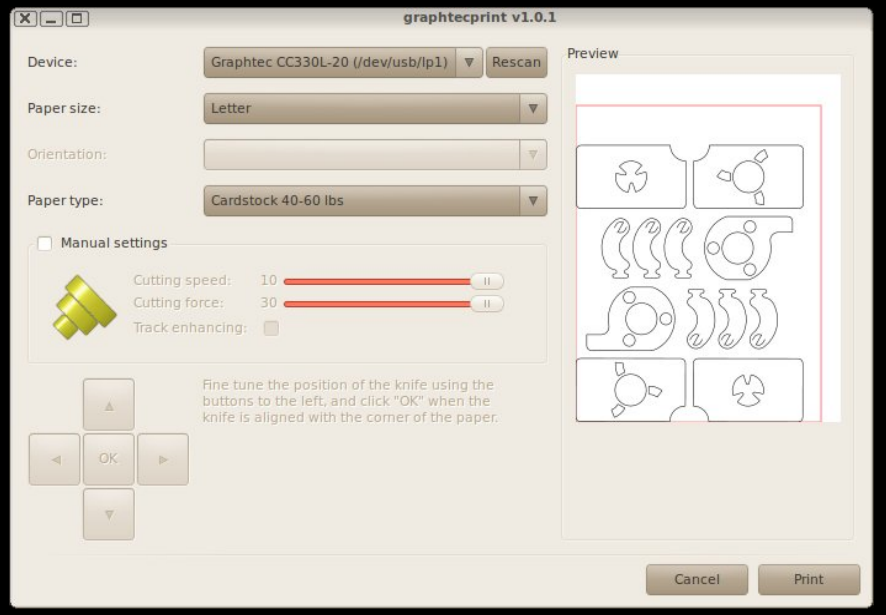
Making The Iris Card



- There are just 6 parts to make & assemble
- Assembly involves folding & tape/glue
- The design is an SVG or PDF file

Making The Iris Card





- Cutting pattern ***must be straight lines***...
- Used **`inkscape`** to fix & arrange objects, **`graphtecprint`** to print

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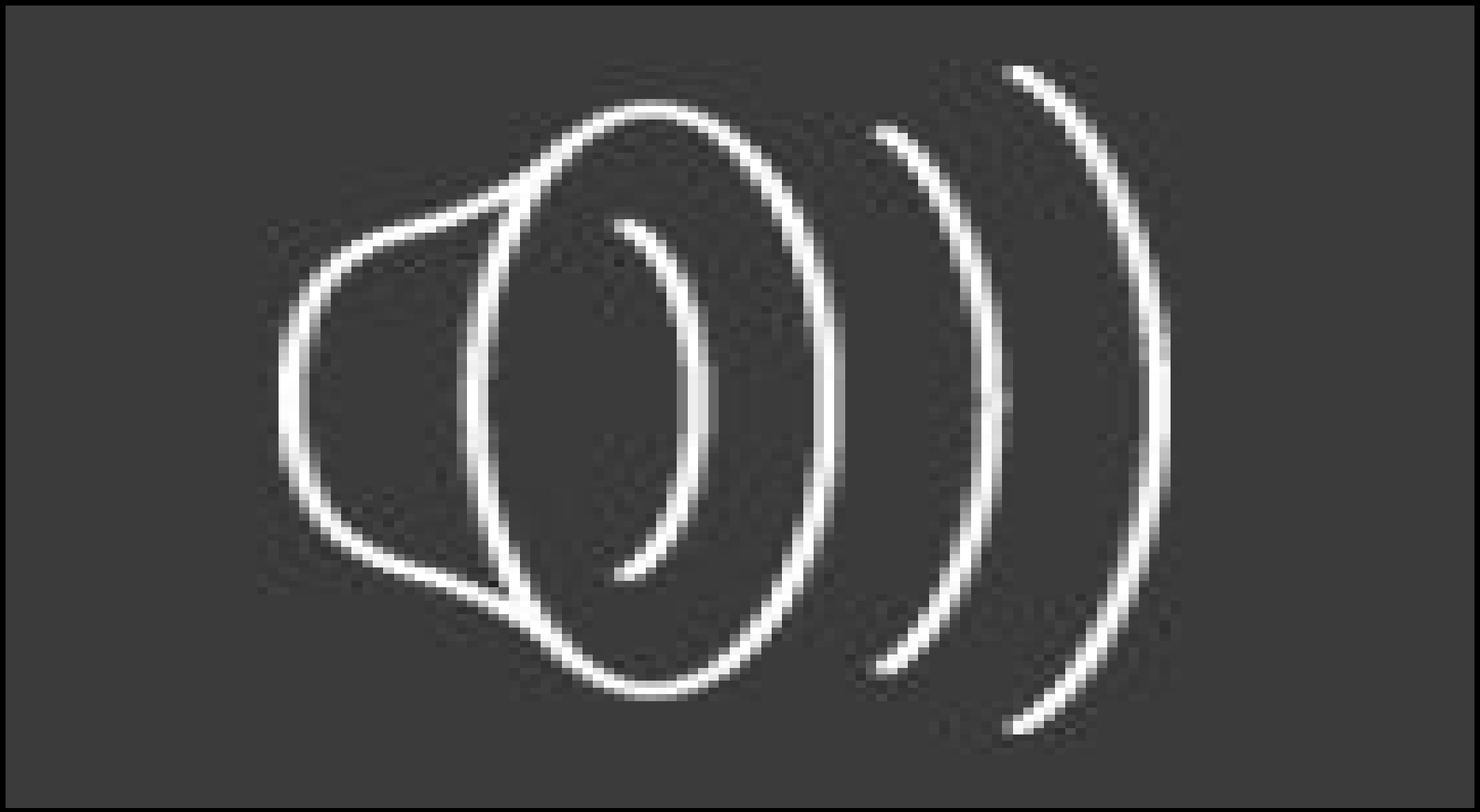
Making The Iris Card



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Additive Building

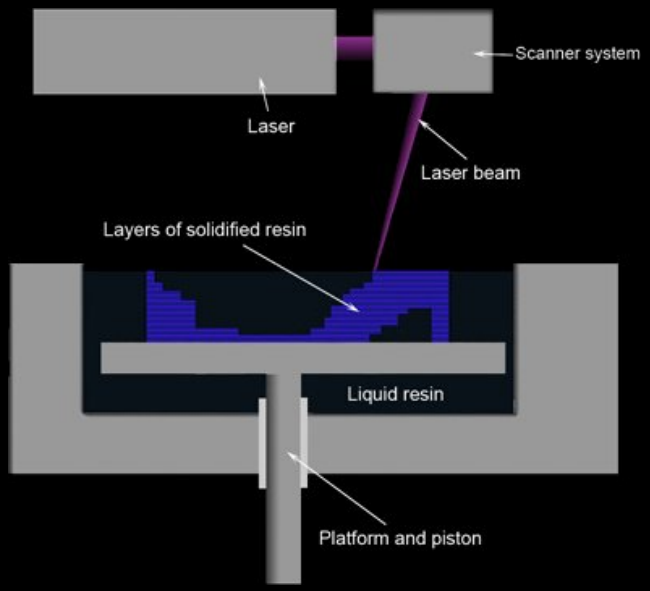
"The whole is greater than the sum of its parts."

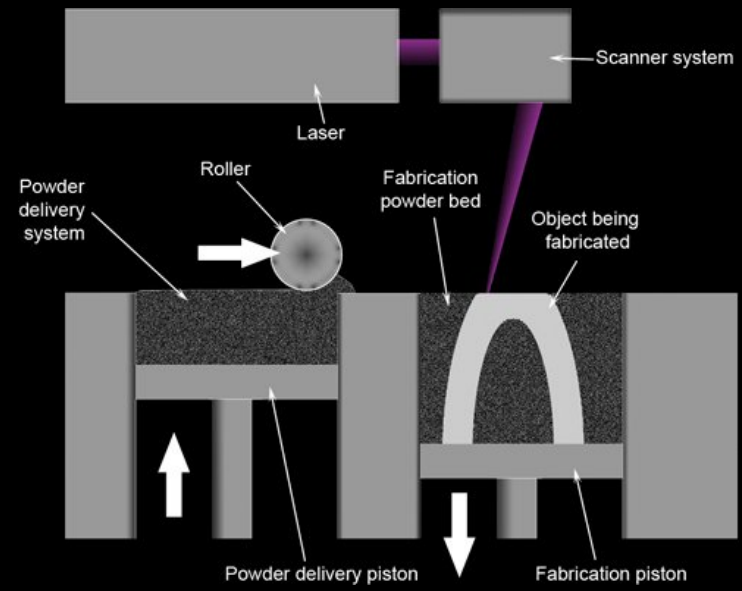
– Aristotle

Additive 3D Building

- Material is deposited, not taken away
- Only works with specific materials
  – powders or paper
  – curable photopolymer liquid resin
  – extrudable materials (mostly plastics)
- No need to get tool around material; can build things with internal structure
- Simpler “clamping” of the part

3D With Lasers



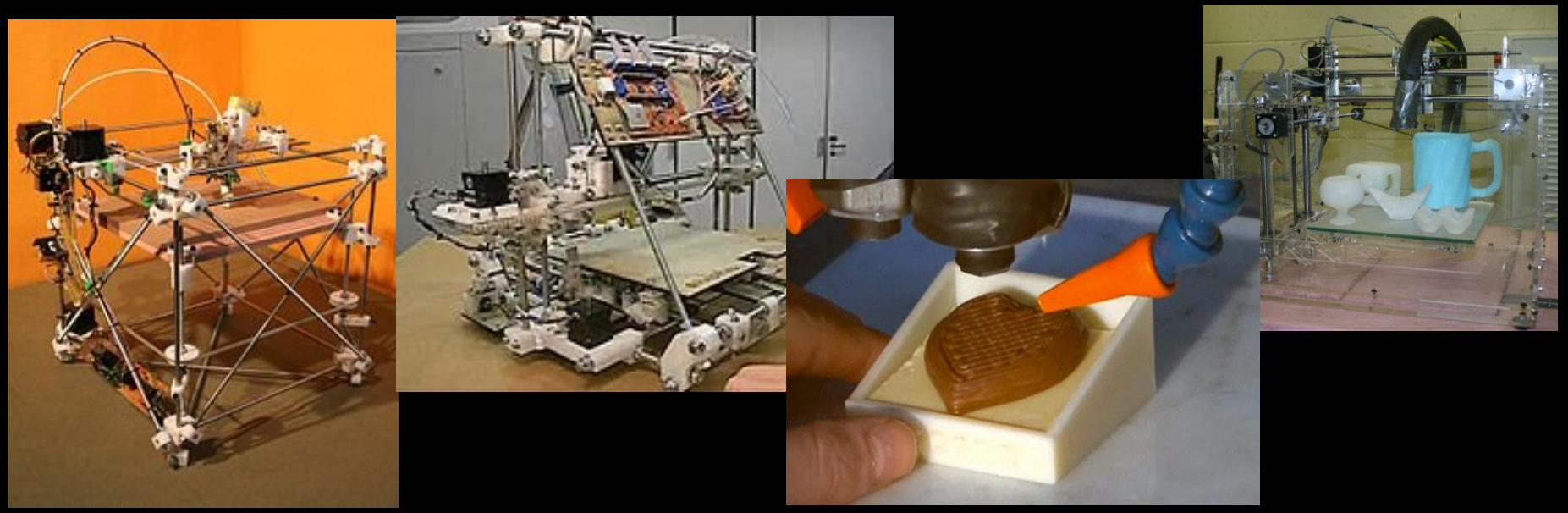


- SLA: Stereolithography of photopolymer
- SLS: Selective Laser Sintering of powder
- SLM: Selective Laser Melting of powder

3D With Glue

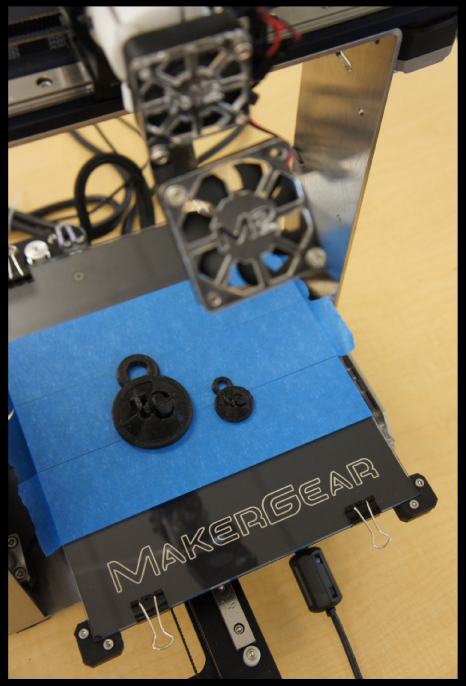
- Layers of paper: printed with glue & cut
- Layers of powder: printed with glue
- Can also be printed in full color

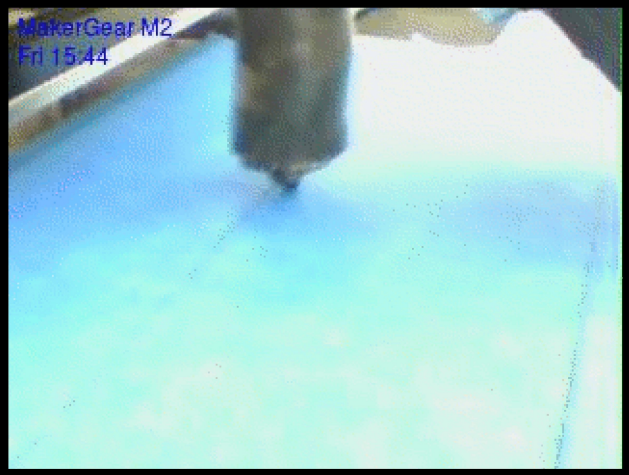
3D Extrusion (RepRaps)



- FDM: Fused Deposition Modeling
- FFF: Fused Filament Fabrication
- Typically ABS or PLA plastic filament…
  but chocolate, water, etc. can be extruded

Our 3D Printer

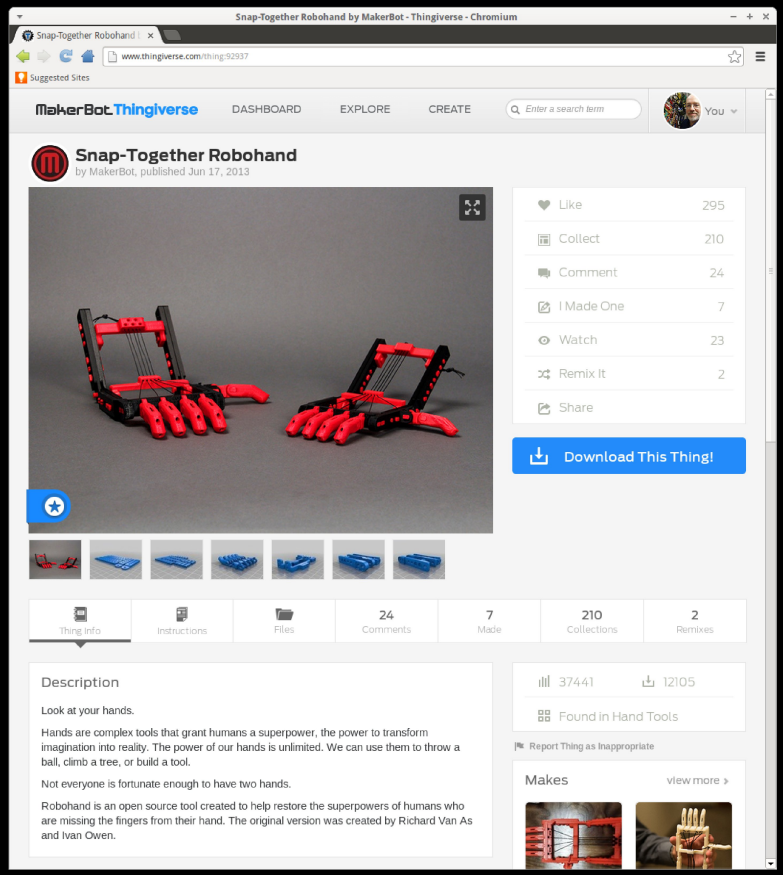




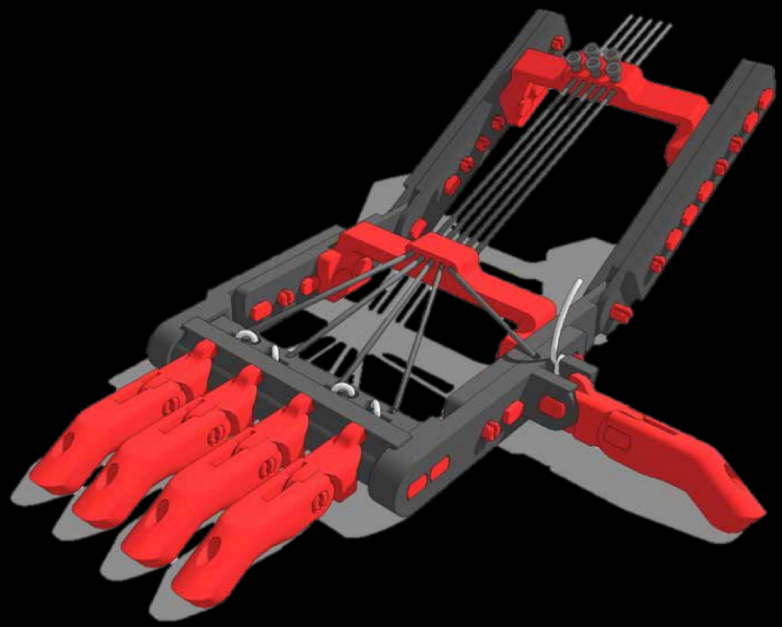
- It's a MakerGear M2, cost about $1700
- We extrude 1.75mm diameter PLA filament to make 0.25mm tall “threads”
- PLA extrudes around 180° – 210°C
- No clamping; extrusion bonds to hot bed

Making A Prosthetic Hand

- Additive 3D
- A working prosthetic hand driven by strings
- Famous design from Thingiverse: Thing 92937



Making A Prosthetic Hand



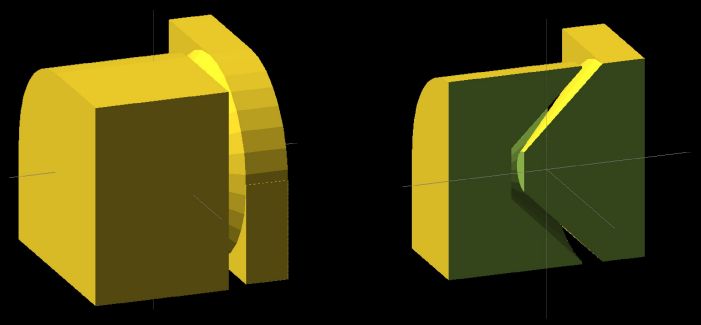
- Start with Thing 92937
- It takes about 6 hours to print
- It takes 3-4 hours to assemble 50+ parts

Making *The* Prosthetic Hand

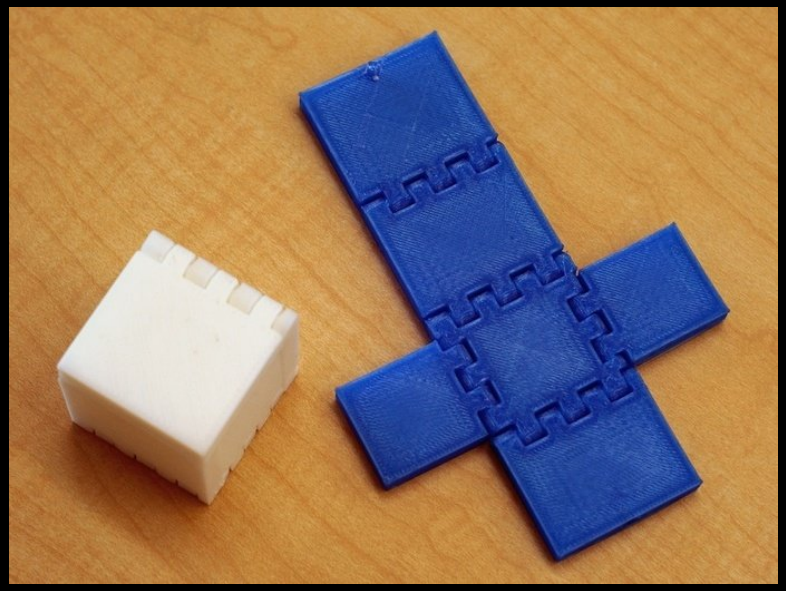
- Let's ***not*** start with Thing 92937 ...
- Redesign from scratch with goals:
  - Faster print time – under 1 hour
  - Print assembled – no snap together parts
  - Better match scale of actual hand
    (sized to 18-month-old girl's hand)
  - Minimum cost – about $1 total

How Do We Print Assembled?

- Easy if no moving parts, right?
  - Can't have unsupported spans
  - Can't have angles shallower than 45°
- How do we print an assembled joint?
  Fortunately, I made this hinge:

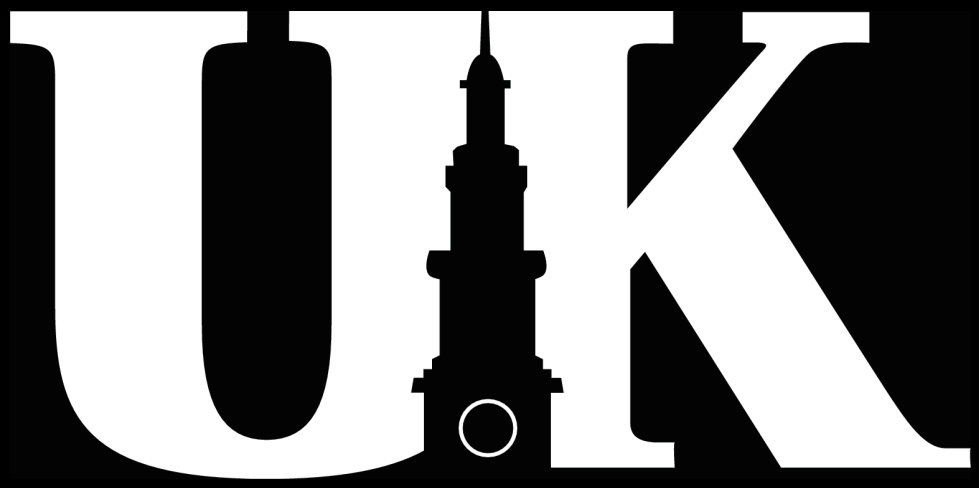


Making The HingeBox



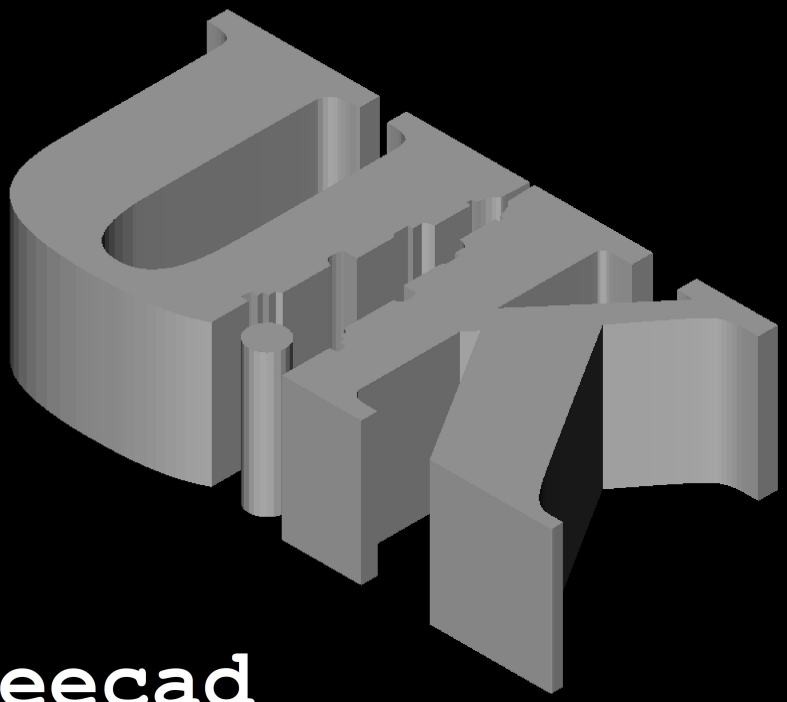
- Created a *hinge library* in `openscad`
- The HingeBox is just a bunch of hinges imposed on two “cubes” plus a latch

Put A UK Logo On It



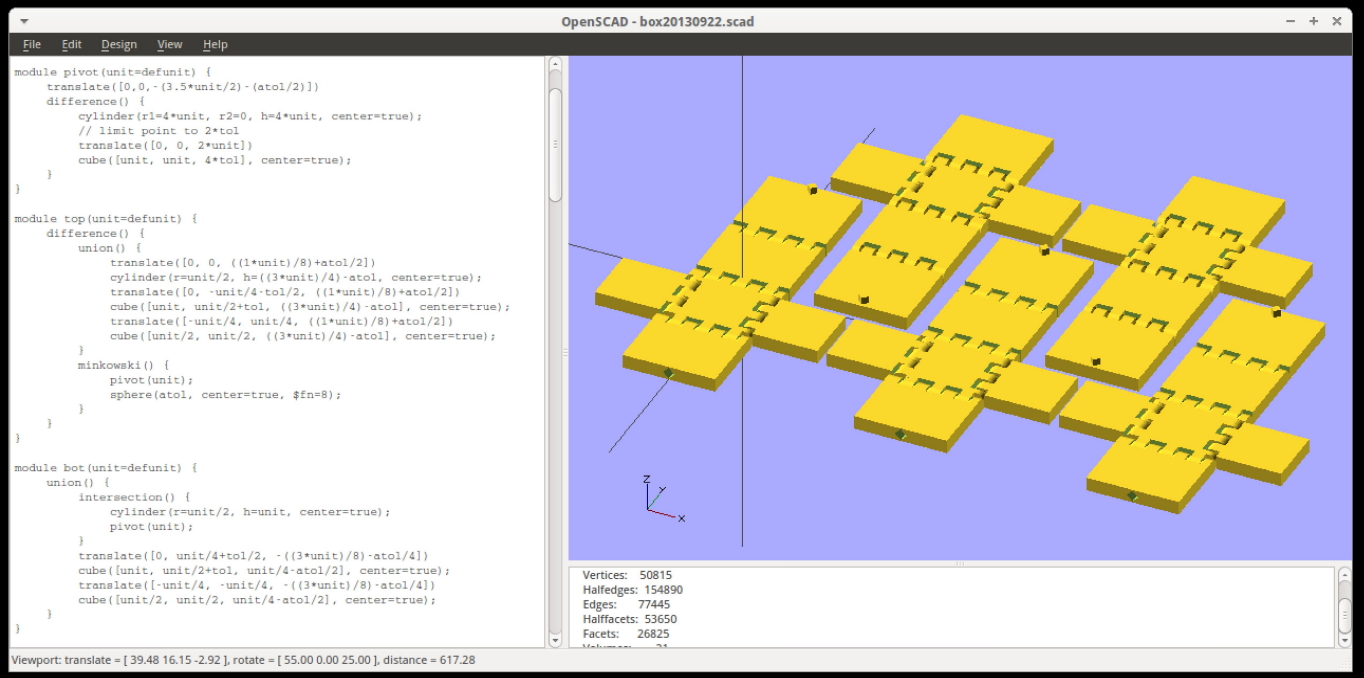
- Start with UK logo
- Use **`gimp`** (an image editor) to simplify it
- Use **`inkscape`** to convert it to DXF vectors

Put A UK Logo On It



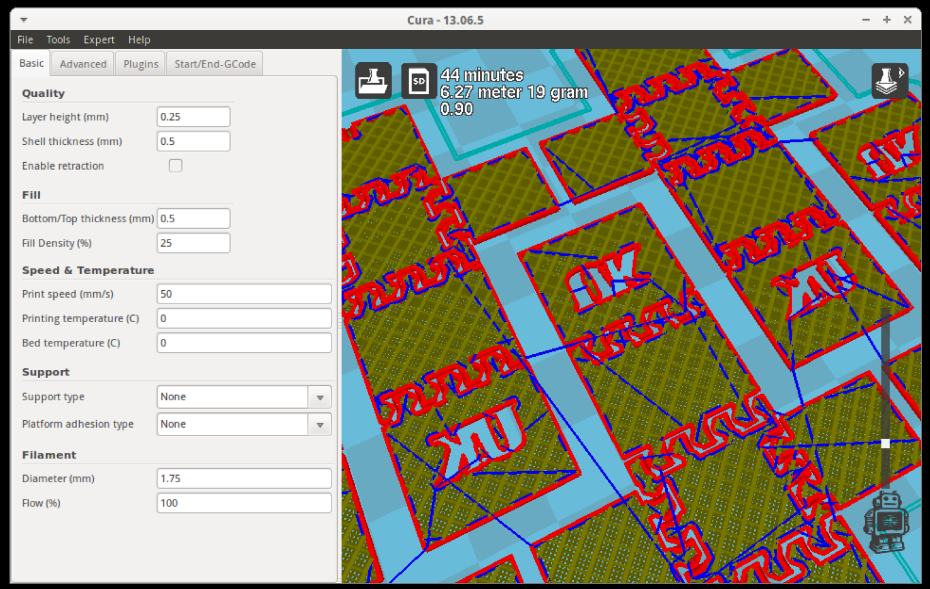
- Load the 2D DXF into `freecad`
- Extrude it to make a 3D STL file
- Use `openscad` to “union” or “difference”

Making The Hinge Box



- An **`openscad`** 3D model is a *program* constructing objects from simple shapes
- Output is an STL model

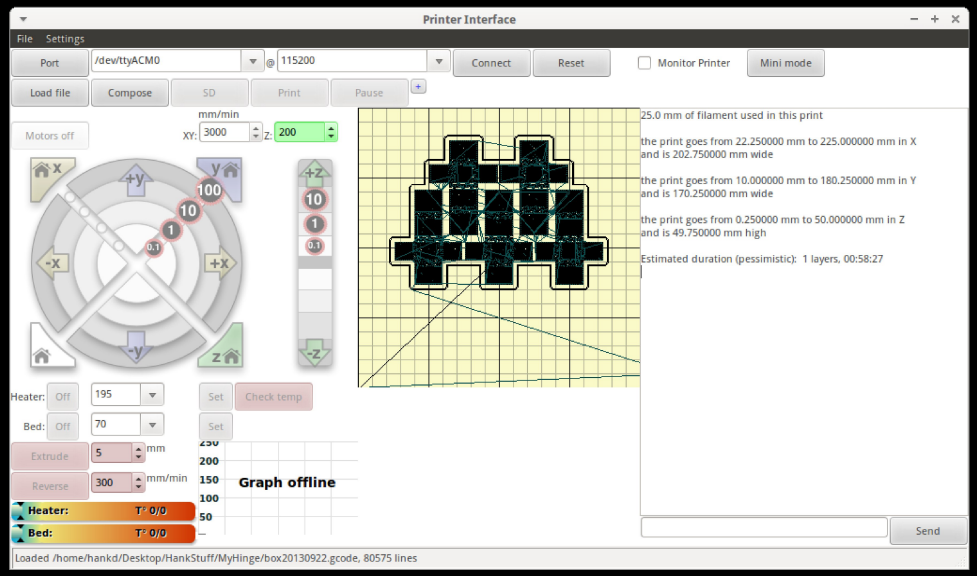
Making The Hinge Box




```
G1 X90.062 Y143.899 E2.97592
G1 X89.502 Y143.229 E3.05532
G1 X88.872 Y142.279 E3.15897
G1 X88.262 Y141.249 E3.26782
G1 X87.812 Y140.339 E3.36013
G1 X82.282 Y126.599 E4.70690
G1 X81.972 Y125.579 E4.80383
G1 X81.432 Y123.169 E5.02841
G1 X81.332 Y122.429 E5.09631
G1 X81.242 Y119.949 E5.32196
G1 X81.252 Y119.199 E5.39016
```

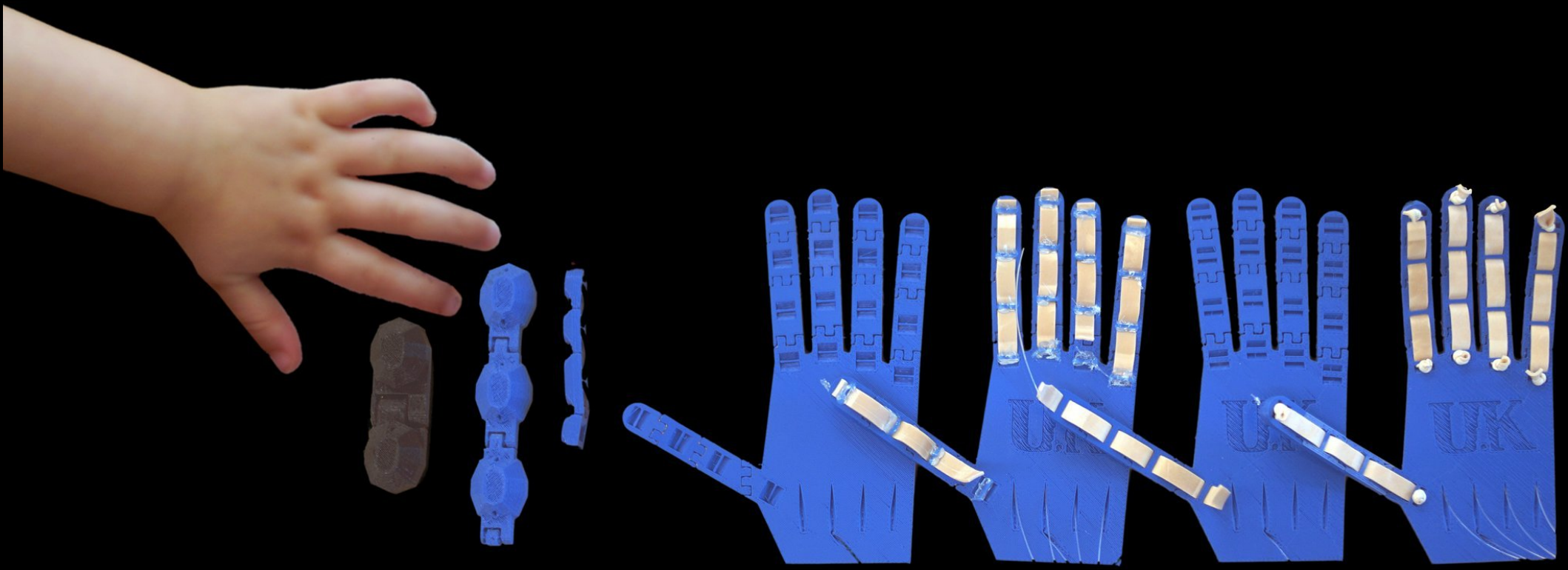
- The STL model is triangles on surfaces
- Slice the solid model using **`cura`**
- Output is gcode – lines in X,Y,Z,E

Making The Hinge Box



- Print gcode using `pronterface`
- **Wait for it...**
- Finished part comes off the cooled bed

Making The Prosthetic Hand



- Did not get it right on the first try…
- Isn't that what rapid prototyping is all about?

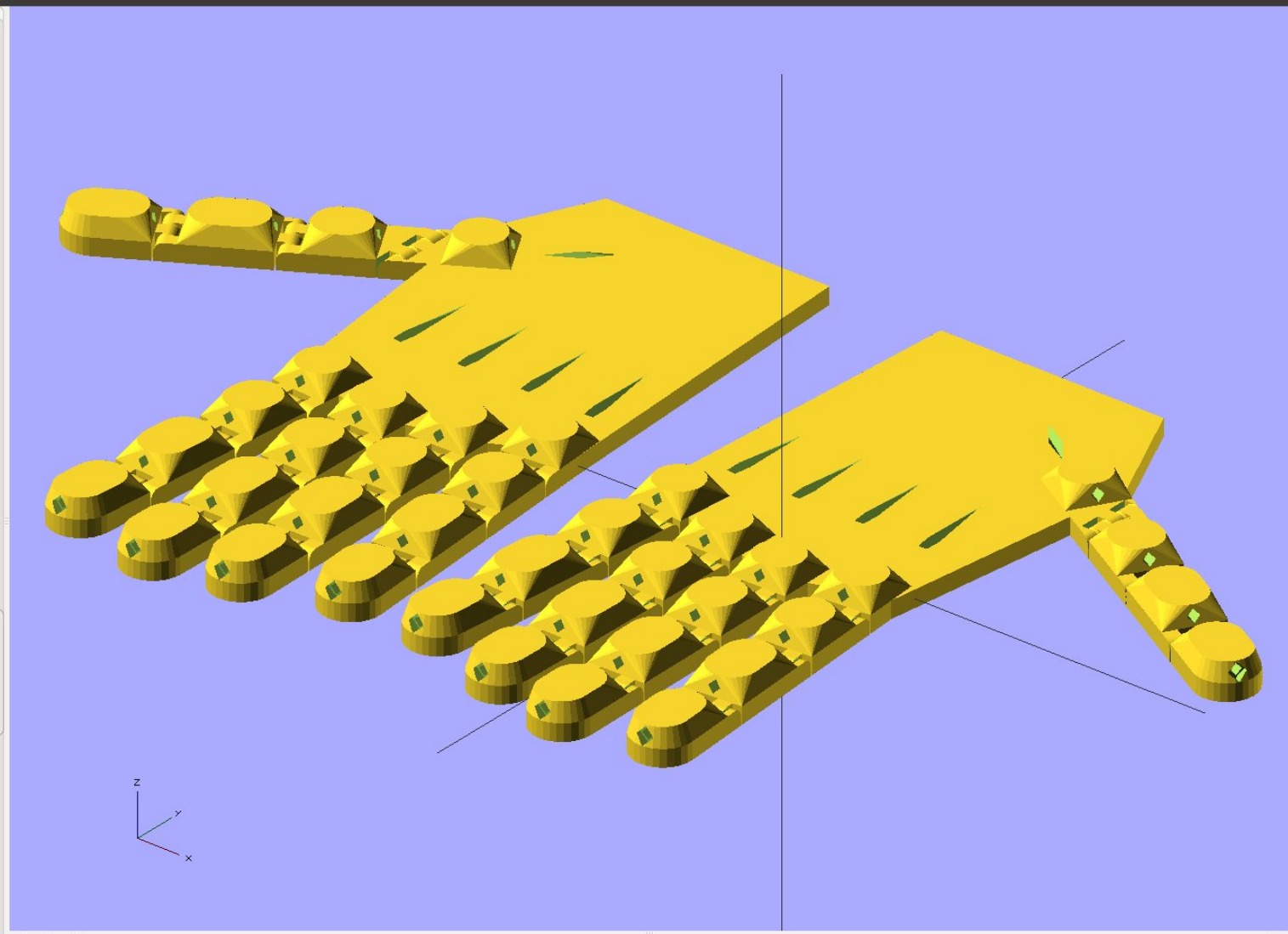
How Does It Work?

- Each finger has 3 joints (hinges) that can bend up to 90° to grasp things
- The thumb also has 3 joints, but one is angled to bring the thumb into opposition
- A rubber band on the back of each finger resets to relaxed non-grasping position
- Fishing line through the fingers and palm is the muscle that pulls the hand closed

OpenSCAD - hand20130925.scad

File Edit Design View Help

```
module fingtip(wide=10, long=11, thick=6) {
    // make a finger segment
    assign(inset=1) // inset of top of finger
    assign(bandwide=6+2*tol) // width of rubber band
    difference() {
        hull() {
            // bottom of segment
            translate([0, long/4, 0])
            cube([wide, long/2, thick/2], center=true);
            translate([0, (long-wide)+wide/2, 0])
            cylinder(r=wide/2, h=thick/2, center=true);

            // top of segment
            translate([0, wide/2, thick/2])
            cylinder(r1=wide/2, r2=wide/2-inset, h=thick/2, center=true);
            translate([0, (long-wide)+wide/2, thick/2])
            cylinder(r1=wide/2, r2=wide/2-inset, h=thick/2, center=true);
        }

        // hole for muscle wire
        translate([0, long, thick/4+sqrt(2)])
        rotate([90, 0, 0])
        cylinder(r=1, h=long*2, center=true, $fn=4);

        // spot to tuck end of muscle wire
        translate([0, long, thick/4+sqrt(2)])
        rotate([90, 0, 0])
        sphere(r=2, $fn=4);

        // loop for rubber band
        translate([0, long-thick/2-(bandwide/2*sqrt(2))/2, -thick/4])
        difference() {
            rotate([0, 90, 0])
            sphere(r=bandwide/2*sqrt(2), $fn=4);
            translate([0, 0, -sqrt(2)*bandstrap])
            rotate([0, 90, 0])
            sphere(r=bandwide/2*sqrt(2)+0.001, $fn=4);
        }
    }
}

module finger(wide=10, long=11, thick=6, nofing=0) {
    assign(firstlong=1*long)
    assign(twolong=1.25*long)
    assign(tiplong=1.25*long)
    union() {
        if (nofing == 0)
        translate([0, wide+thick/4+tol, 0])
        union() {
            translate([0, firstlong+thick/2+2*tol, 0])
            union() {
                translate([0, twolong+thick/2+2*tol, 0])
                union() {
                    hingelen(wide, thick/2);
                    translate([0, thick/4+tol, 0])
                    fingtip(wide, tiplong, thick);
                }
                hingelen(wide, thick/2);
                translate([0, thick/4+tol, 0])
                fingseg(wide, twolong, thick);
            }

            hingelen(wide, thick/2);
            translate([0, thick/4+tol, 0])
            fingseg(wide, firstlong, thick);
        }

        difference() {
            // hand base
            fingseg(wide, wide, thick);
            translate([0, -wide, 0])
            cube([2*wide, 2*wide, 2*thick], center=true);
        }
    }
}


module thumb(wide=10, long=11, thick=6) {
```



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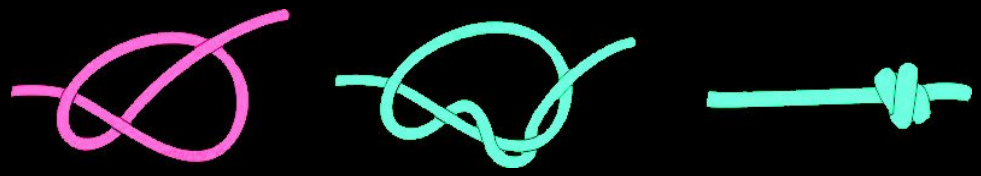
Halfedges: 99064
Edges: 49532
Halffacets: 39020
Facets: 19510
Volumes: 39
Total rendering time: 0 hours, 20 minutes, 0 seconds

Viewport: translate = [-19.59 -5.07 7.81], rotate = [60.60 0.00 39.00], distance = 762.08

Making The Prosthetic Hand



- Check all hinges are free to move
- Insert rubber bands on backs of fingers:
  Cut band, knot one end & trim the other, work through slots & tighten, knot & trim
- Route fishing line through fingers:
  Push line through palm & finger, knot end at finger tip, trim after about two hand lengths

Questions?

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