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
Making The Iris Card
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

- **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.
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?

Aggregate.Org
UNBRIDLED COMPUTING
University of Kentucky
Electrical & Computer Engineering