3D Printing

MARCO CALLIERI
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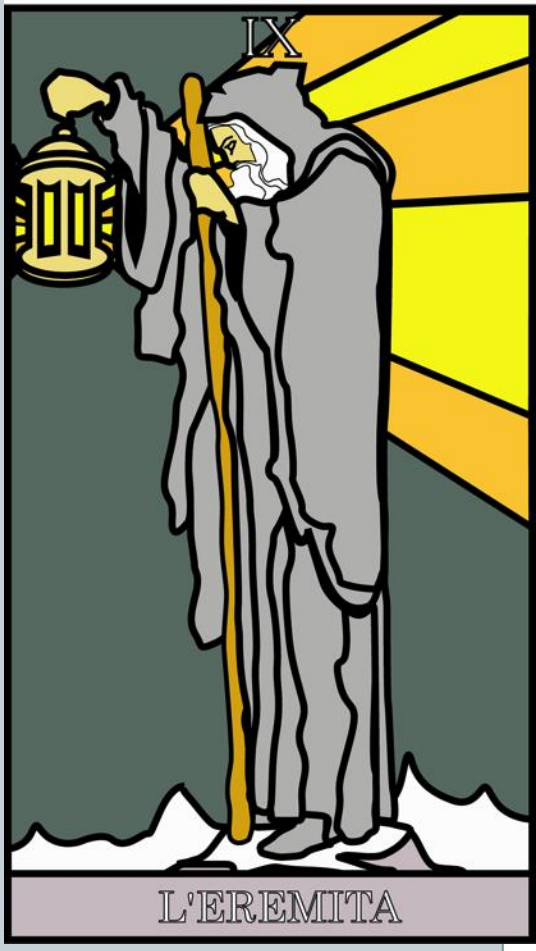
Chi sono?

Marco Callieri

- Master degree & PhD in computer science

- Researcher at the Visual Computing Lab, ISTI-CNR, in Pisa
- I work on 3D data manipulation and rendering... lot of experience in 3D scanning and data processing
- Most of my activities are in the field of cultural heritage



http://vcg.isti.cnr.it/~callieri

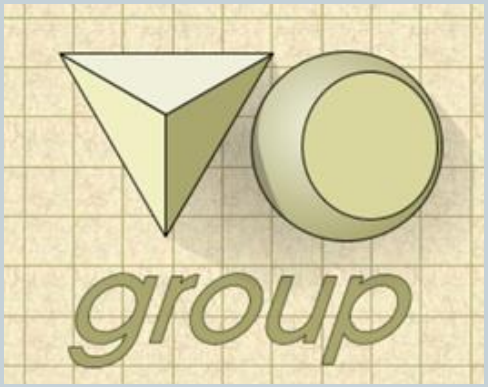
Beside this:

an eclectic artisan, an avid gamer, a former biker, a good cook, an incorrigible geek... and much more

Visual Computing Lab

Gruppo di ricerca dell'ISTI (Istituto di Scienza e Tecnologie dell'Informazione), istituto del CNR...

Siamo nell'area di ricerca di Pisa; siamo circa 20 persone, che lavorano su diversi aspetti della Computer Graphics



http://vcg.isti.cnr.it

Buzzword

3D Printing is a “buzzword”

buzz·word (bŭz'wûrd)

n.

1. A word or phrase connected with a specialized field or group that usually sounds important or technical and is used primarily to impress laypersons

Everyone is talking about 3D printing, and seems everything may be solved with 3D printing… (just like “drones”, “social media”, “3D”…)

The story so far

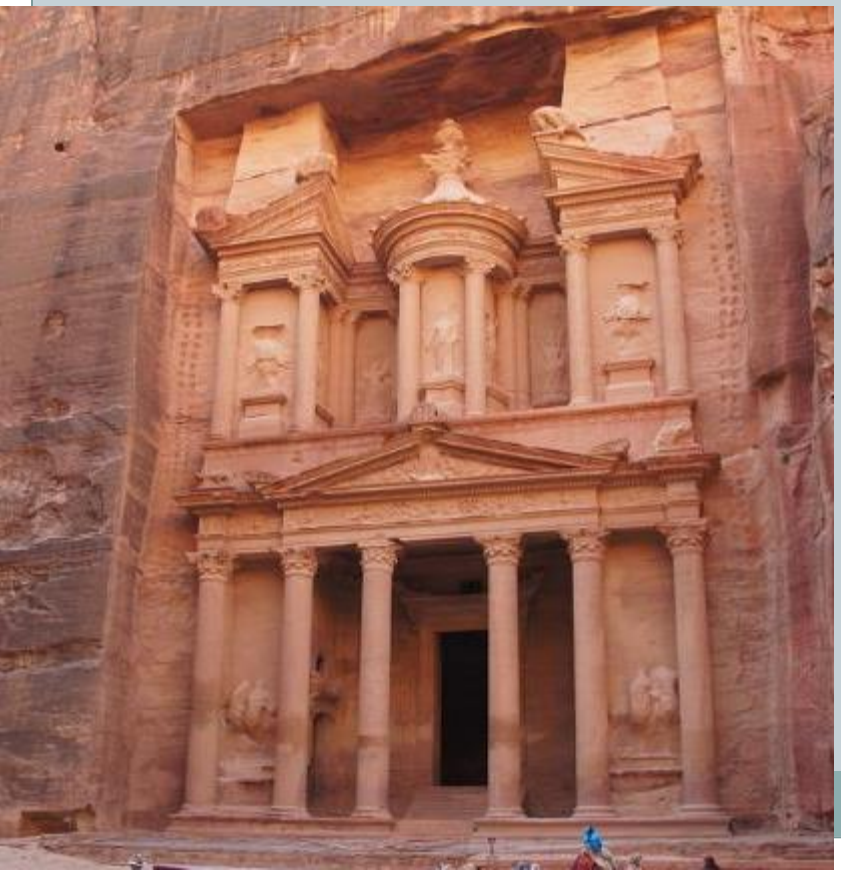
The problem is…

3D PRINTING IS NOT A NEW TECHNOLOGY

3D printing derives from a much *wider* and *older* family of technologies, called RAPID PROTOTYPING which, in turn, is a subset of of an even wider one, called CAM (Computer Aided Manufacturing)

Ancient Concepts

Subtractive



Additive

The story so far

The oldest CAM tools are simply a series of milling / cutting / drilling heads, controlled by a PC.

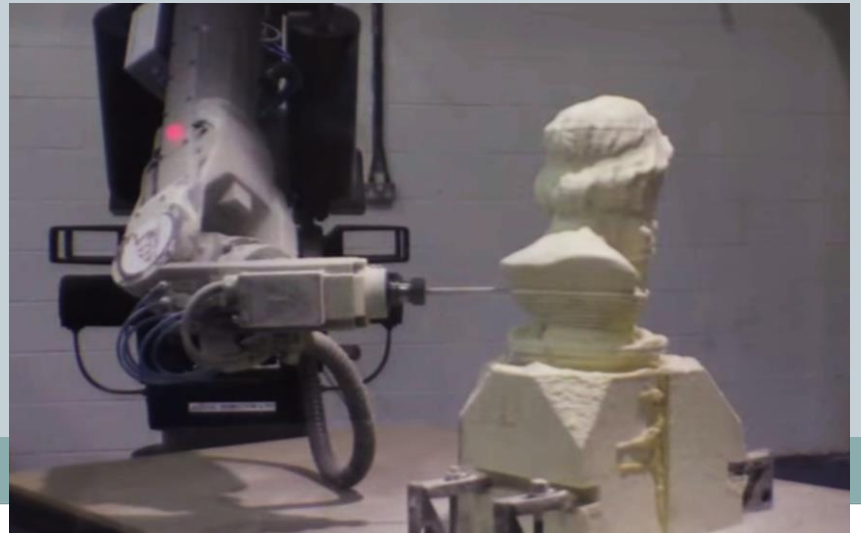
CNC machines are still used a lot today, and they can be considered the origin of the Rapid Prototyping...

The story so far

CNC machines, however, may only build a limited subset of geometries, depending on their working tools…

New machine could carve increasingly more complex objects

- 2.5 D drill/router (only produces a “height field”)
- 3-4-5-…N axis carving machines (tuttotondo)



The story so far

Many different milling / carving techs.

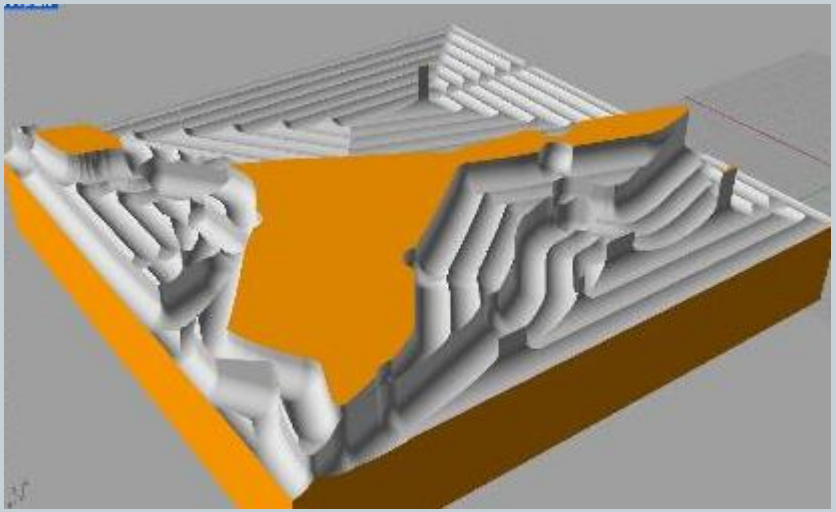
Size and shape of the carving tool affect the quality of the results

- Bigger/rougher means faster
- Smaller and more precise means slower

Milling paths:

How to move the carving head

Over the surface of the object is THE problem.



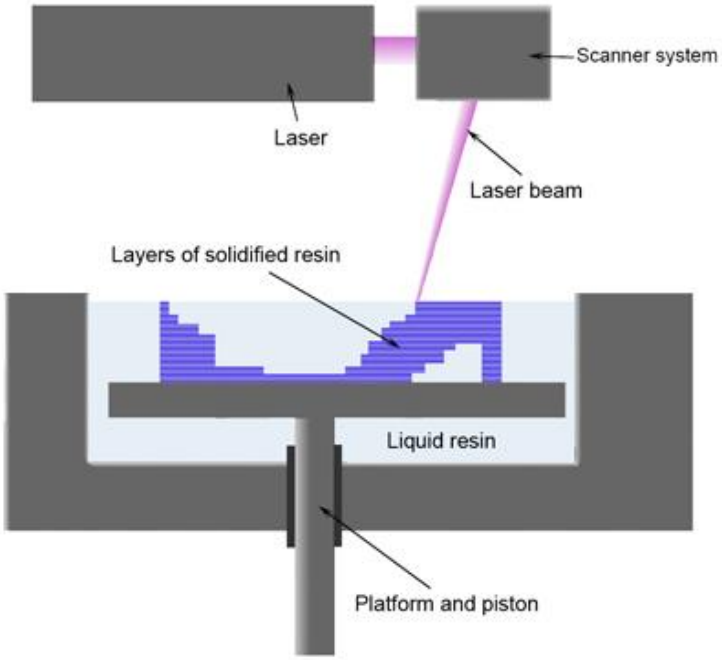
Up to a certain point, only SUBTRACTIVE technologies were available… then, came Stereolithography

Stereolithography (SLA)

The most famous old-school (1986) **additive** method for rapid prototyping: a liquid resin is solidified, layer by layer, using a laser.

Really costly, but creates incredibly detailed, sturdy objects

Used **a lot** in automotive!



Stereolithography

Stereolithography

http://www.materialise.com/

One of the oldest and biggest companies providing additive rapid prototyping as a service (you provide the 3D model, they print it).

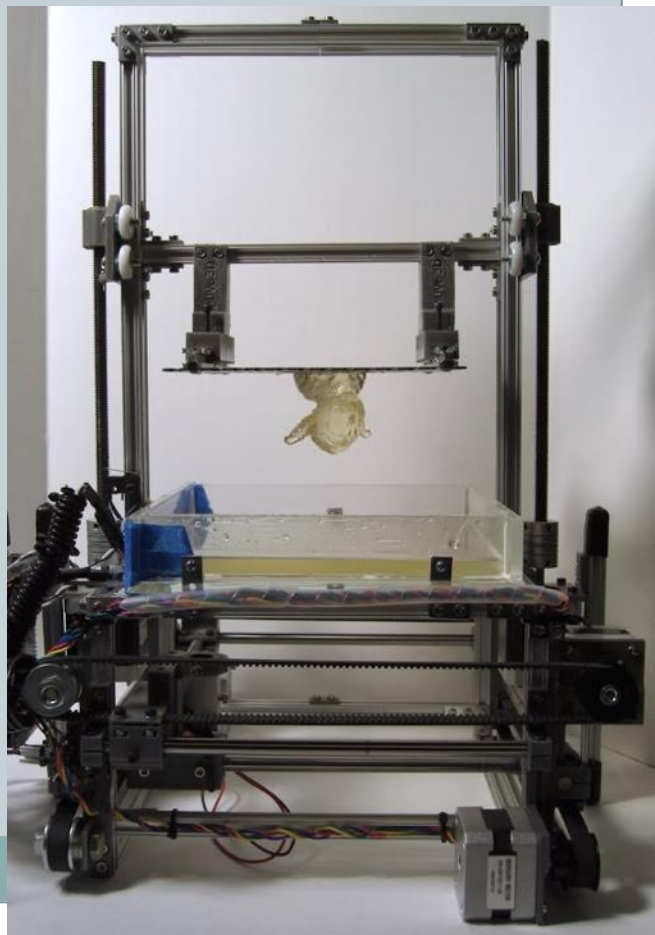
We used them years ago to make a David head.
They have the largest printing vats in the market !!

“almost” at home

Difficult to use at home… it uses laser, a vat full of resin, and require a lot of maintenance…

BUT

There are some experiments and new commercial printers to do “desktop” stereolithography… however, they are still in their infancy…



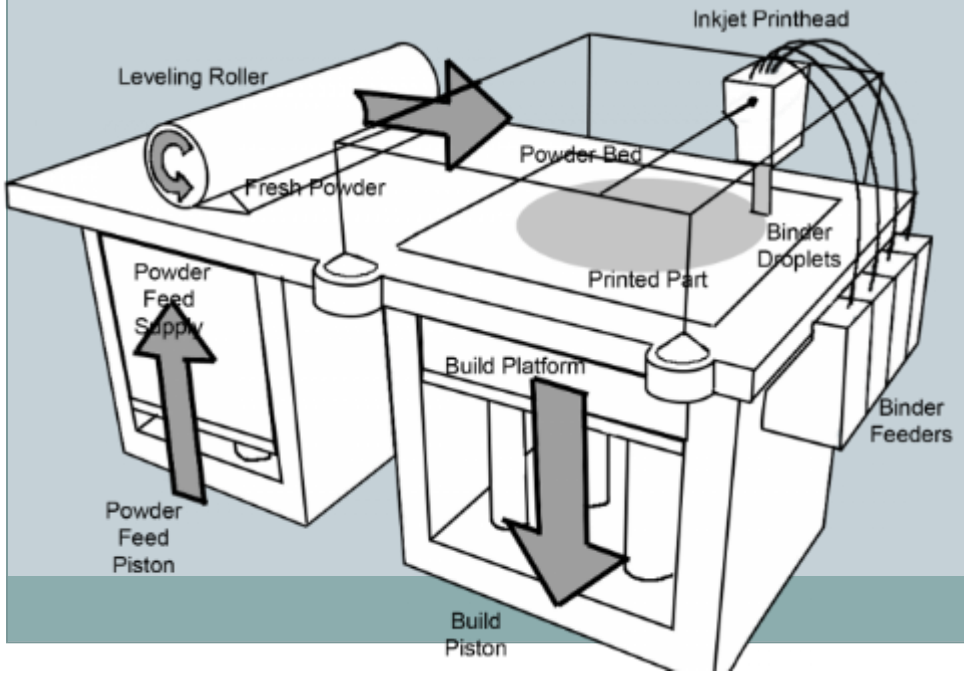
“almost” at home

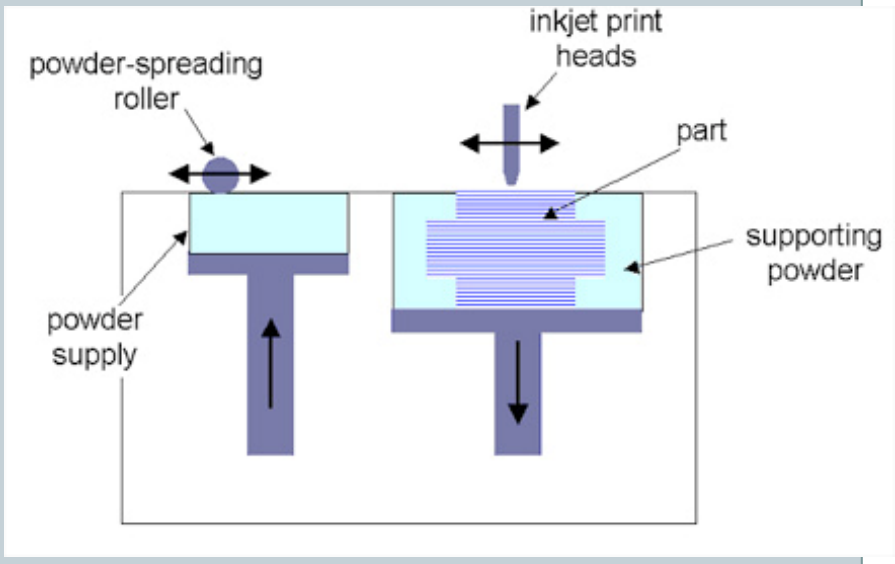
http://http://formlabs.com/en/products/form-1-plus/

Other technologies

CHALK/powder printers

The printer deposits a layer of powder in a vat, then an inkjet head sprays glue on the “surface” of the object… Layer after layer the vat is filled, the object, now solid, is dug out from the powder…



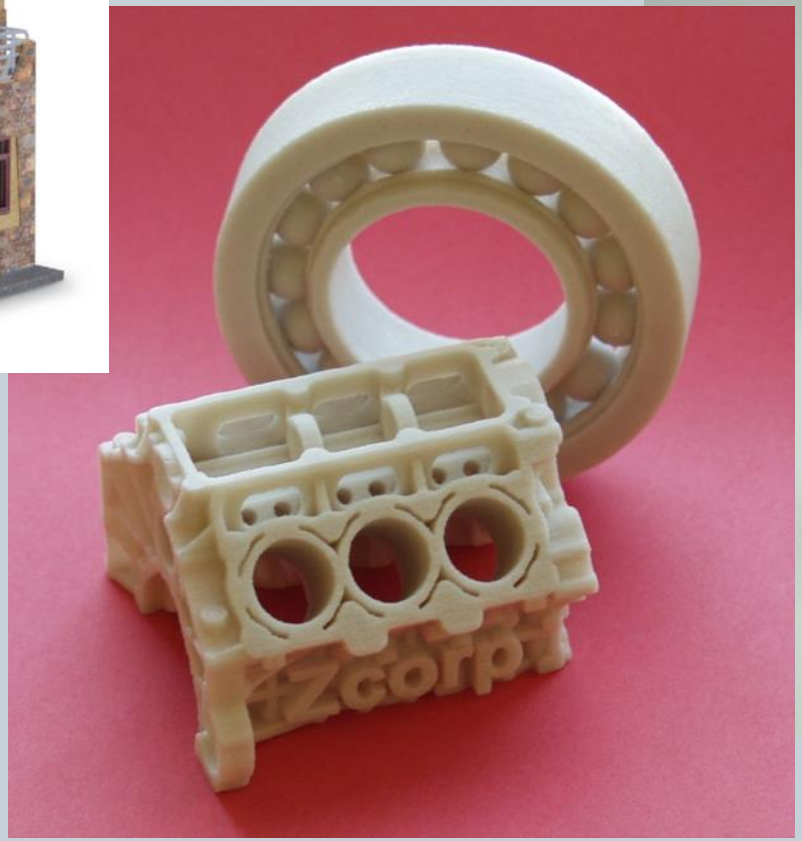


Other technologies

- No desktop use: industrial machine requiring maintenance
- Slow and high cost
- Fragile

+ High detail
+ Can do color prints
+ No problems with overhangs (I’ll expalin later)
+ The “feel” of the object is good for some markets

Other technologies



What happened, then

The current 3D printing trend is the result of different factors

- Industry developer new technologies for the creation of physica objecs from 3D models
- Huge increase in the use of 3D models
- Cheaper hardware
- Popularization of the technology thanks to independent people aiming at developing open-hardware for 3D printing

3D Printing as we know it

3D printing, even if is used for any technology, is the name for all those technologies using an additive, layer by layer strategy, akin to “standard” 2D printing…

More specifically, with 3D printing, we generally indicate:

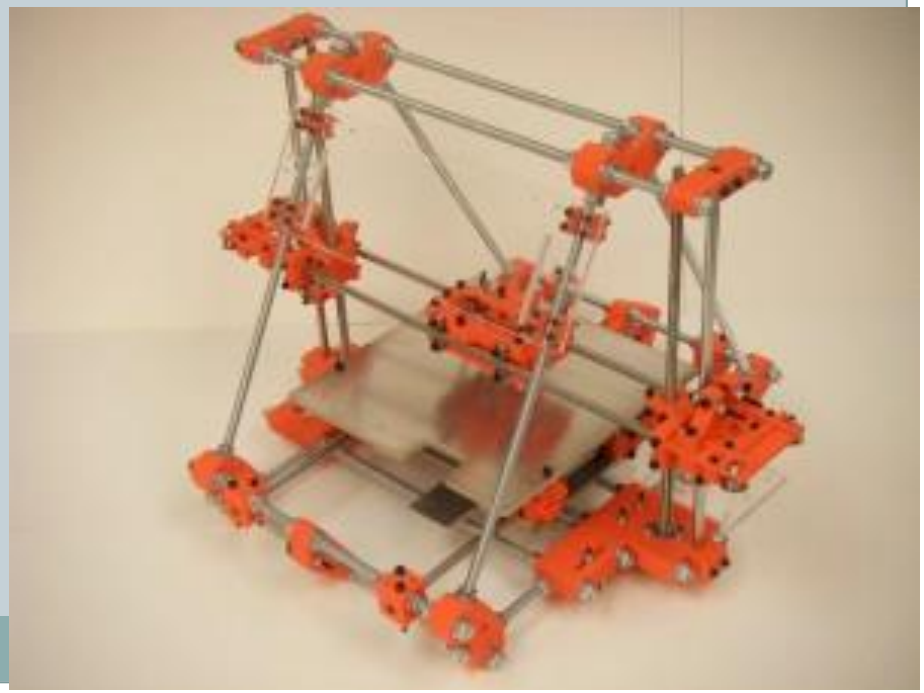
- Desktop, Do-It-Yourself, Home-safe printers
- Low cost approach (w.r.t. industrial solutions)
- ???

The “open” approach

A group of enthusiasts, technicians and researchers started designing a machine able to print itself (!!)

So… simple mechanism for depositing material, and simple architecture.

The project was called **RepRap**

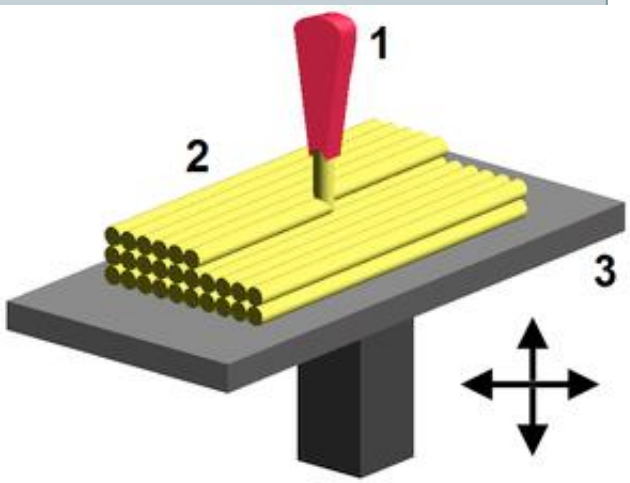


The “Fused Filament” method

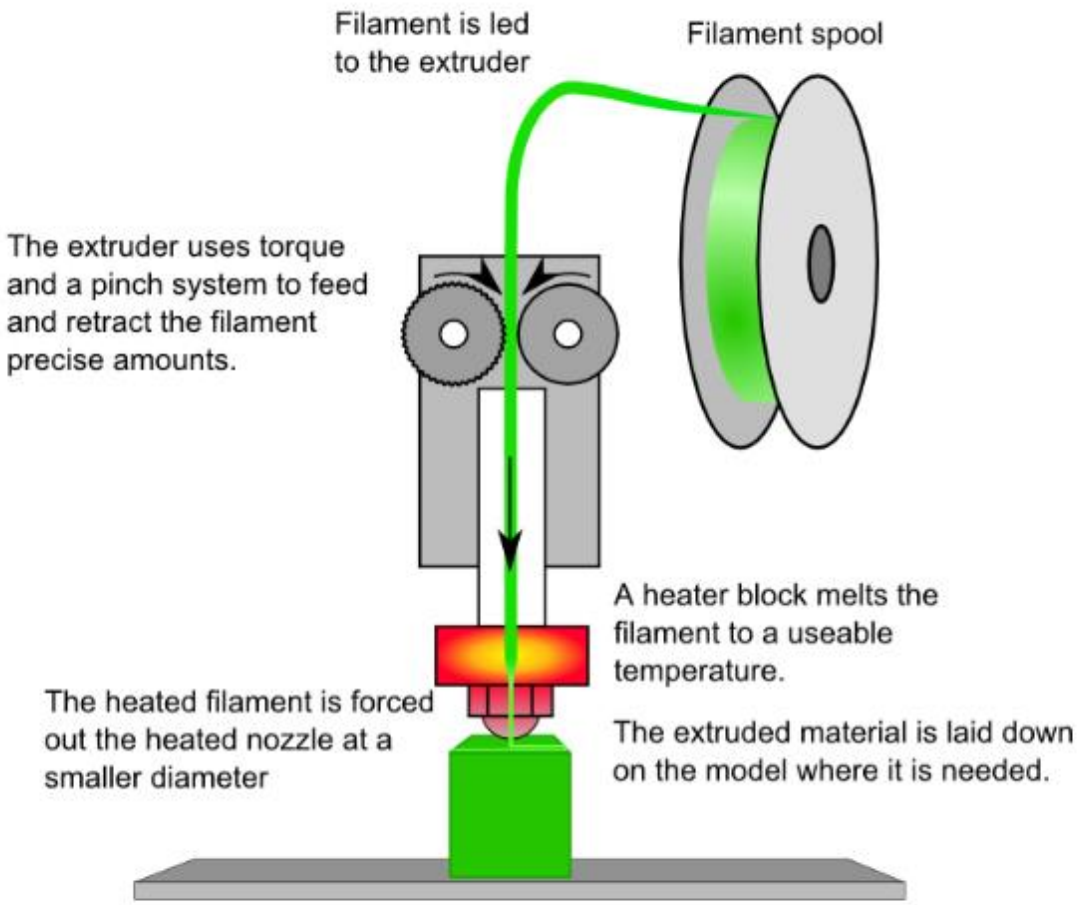
It was necessary to find a printing method which was simple, easy to do with common hardware, suitable for a “desktop environment”… **fused deposition modeling** (sotto copyright) o **fused filament fabrication**

- The printing material is plastic, stored as filament on a spool
- The material is heated to its melting point, and deposited in layers

(this method was also used in industrial printers)

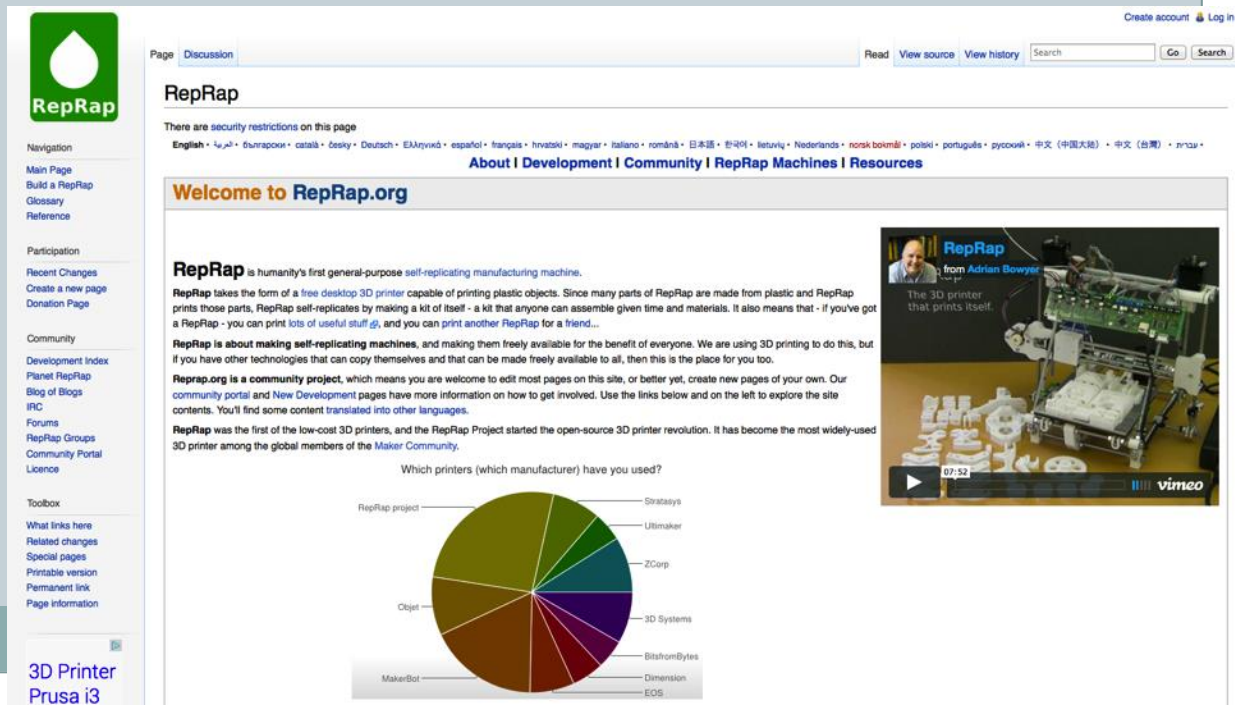


FDM


Filament is led to the extruder
Filament spool
The extruder uses torque and a pinch system to feed and retract the filament precise amounts.
A heater block melts the filament to a useable temperature.
The heated filament is forced out the heated nozzle at a smaller diameter
The extruded material is laid down on the model where it is needed.
The print head and/or bed is moved to the correct X/Y/Z position for placing the material

The “open” approach

The RepRap project evolved a lot in the years, now there are different “blueprints” for whole printers, electronic components for printers, extruders… There are many “derived” models, kits on sale, and companies/fablabs helping you build your own DIY printer…

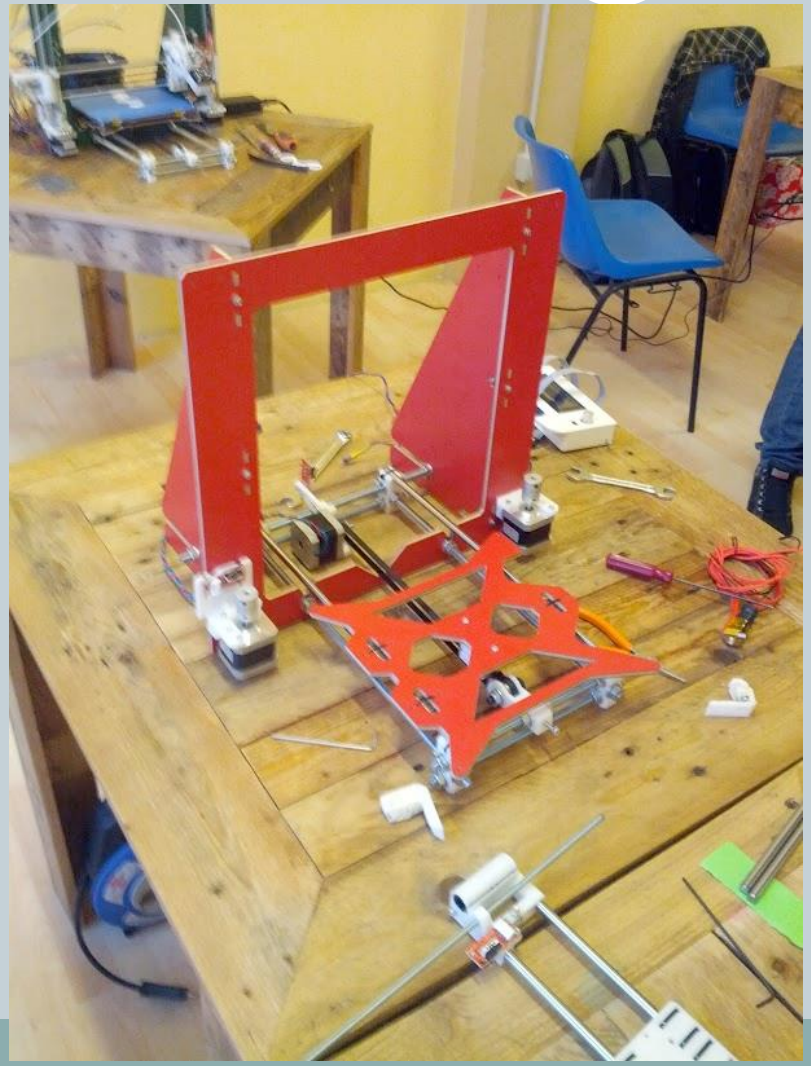


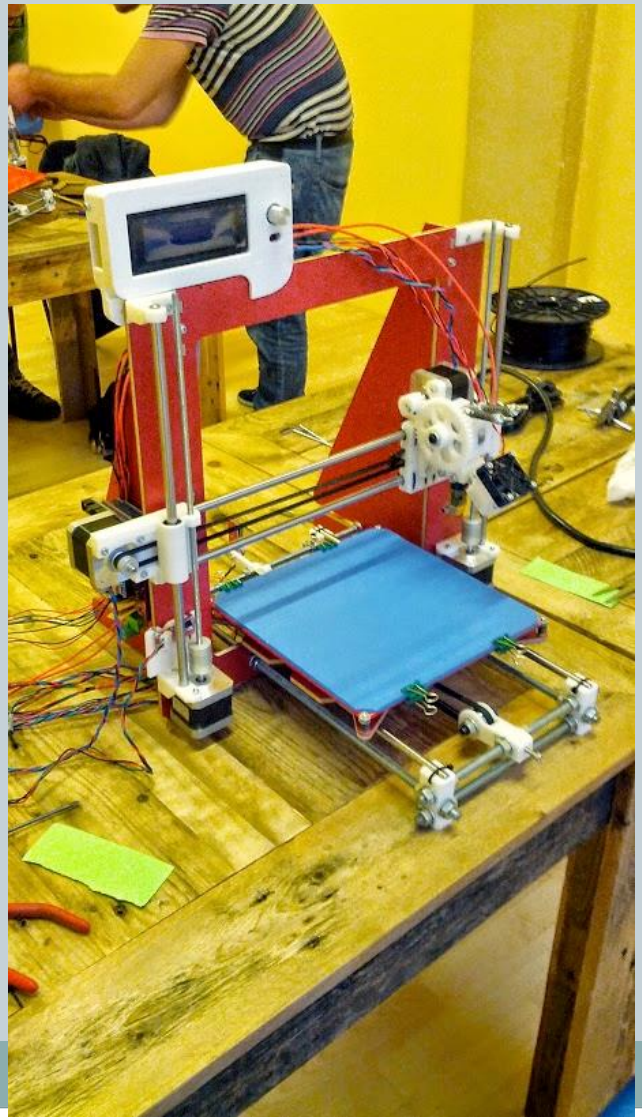
A Do-It-Yourself Printer

Prusa i3

A Do-It-Yourself Printer

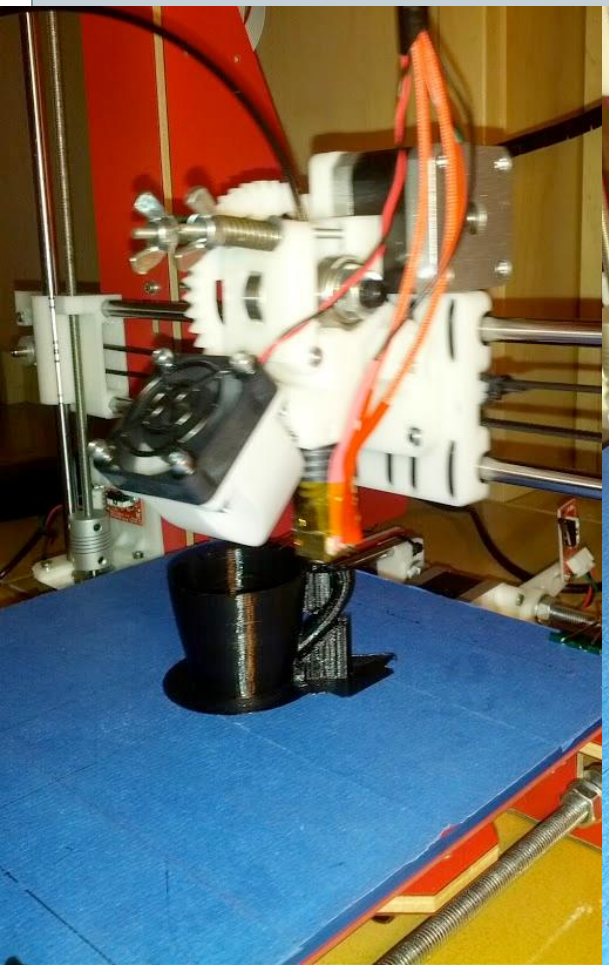
Prusa i3





A Do-It-Yourself Printer

Prusa i3

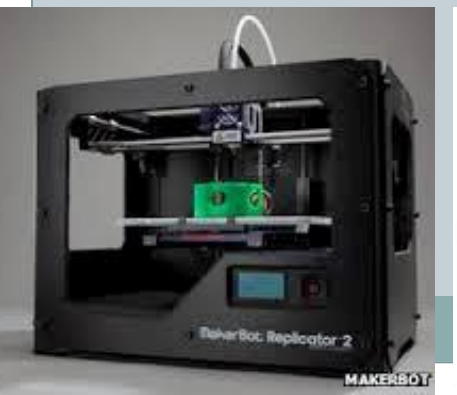


An entire ecosystem

Directly forking from RepRap, or inspired by it, a number of other 3D printers have sprouted…

Open, close, semi-open, open projects with closed parts, free software, open source software…

It is a **mess** just to understand what is available on the market



An entire ecosystem

Beside the cost/print size/resolution…. Things to look for:

- Is the hardware open? Is it possible to open/dismantle the parts to clean/repair them?

- Which material can I use? Can I use third part material?

- Is the software included? Is it open? Can I use third-part software?

- Can I manage the build/operation/maintenance ?

READ REVIEWS!!! Ask on forums… Internet is good to find reliable feedback

3D model

A printer needs a “printable” 3D model…

The requirements for the 3D models are many, we will describe them in detail in the next days.

Some are related to the shape and detail…

Some are more “basic”:

- Triangulated
- Closed (mostly)
- Shelled (maybe)
- Topologically clean (as much as possible)

3D model

- Not all 3 models are “directly printable”, but may require conversion/resampling/heavy edit
- When hand-modeling, there are strategies to create printer-friendly geometries

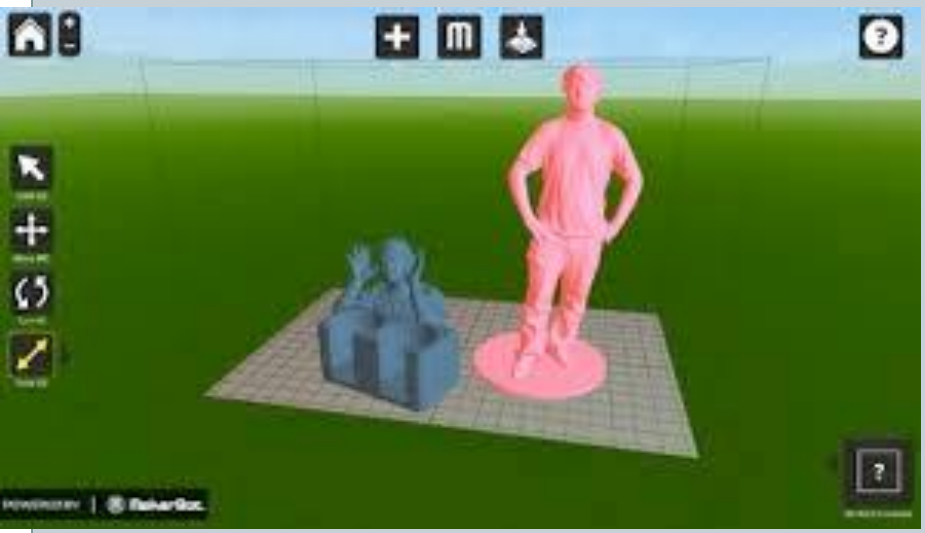
I will try to cover these points, but…

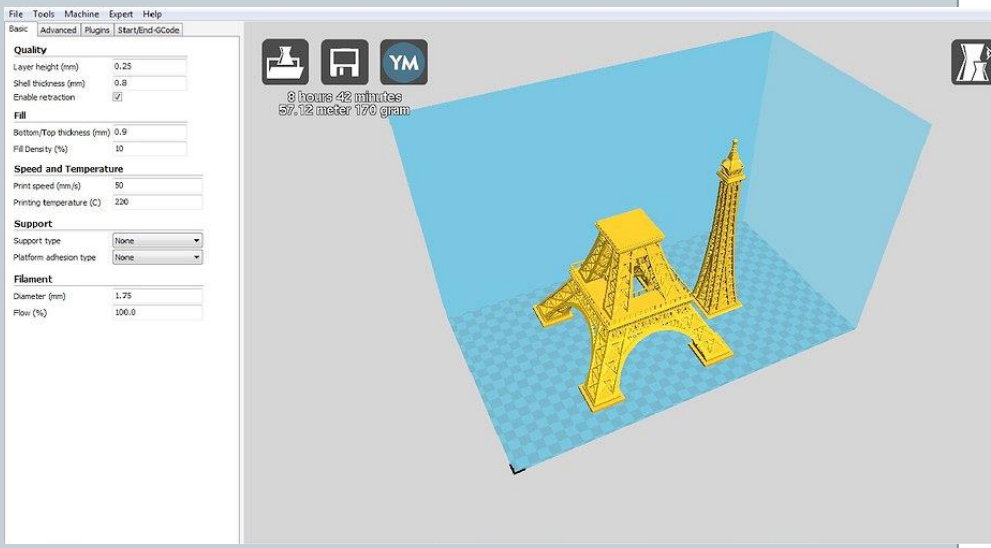
- There will ALWAYS be unprintable 3D Models

Before printing

The printer cannot directly handle a 3D model, but needs clear instruction on how to print it.

A conversion from a 3D Model to instructions is ALWAYS necessary. This processi is called **slicing.**

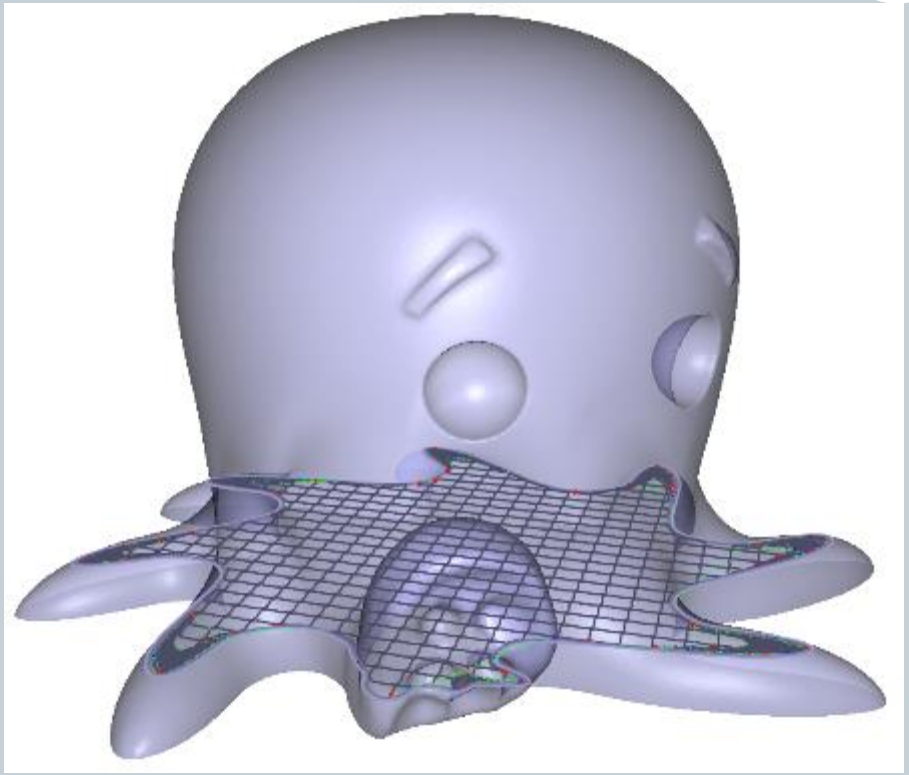


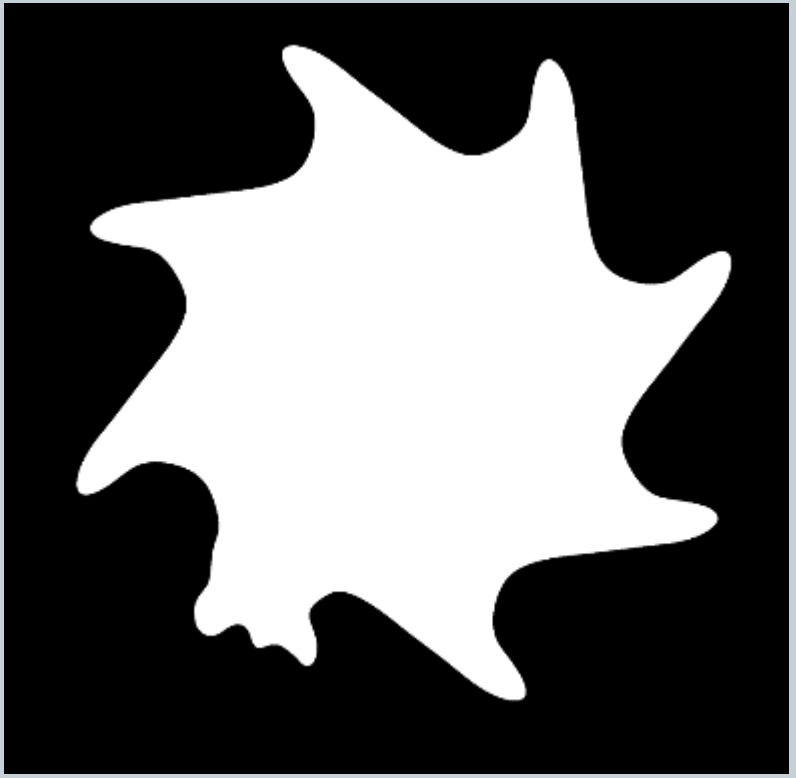


Before printing

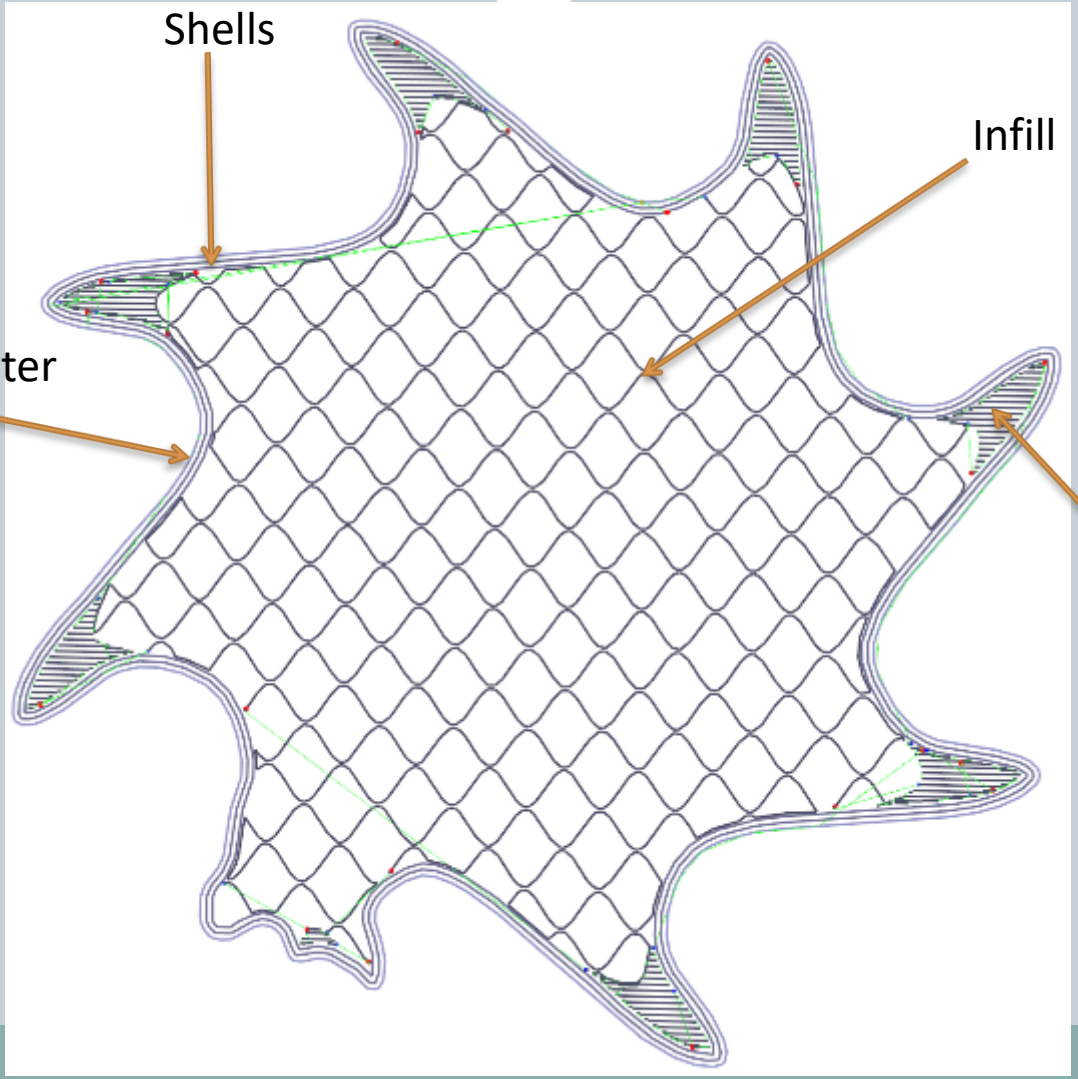
- Many slicing tools, from “single button” to extremely complex
- Different slicing tools will produce different results, some will not even be able to manage certain geometries
- Orientation of the 3D model DOES matter
- Knowing what happens in the slicing software helps a lot
- There will ALWAYS be unprintable geometries

Toolpath Generation

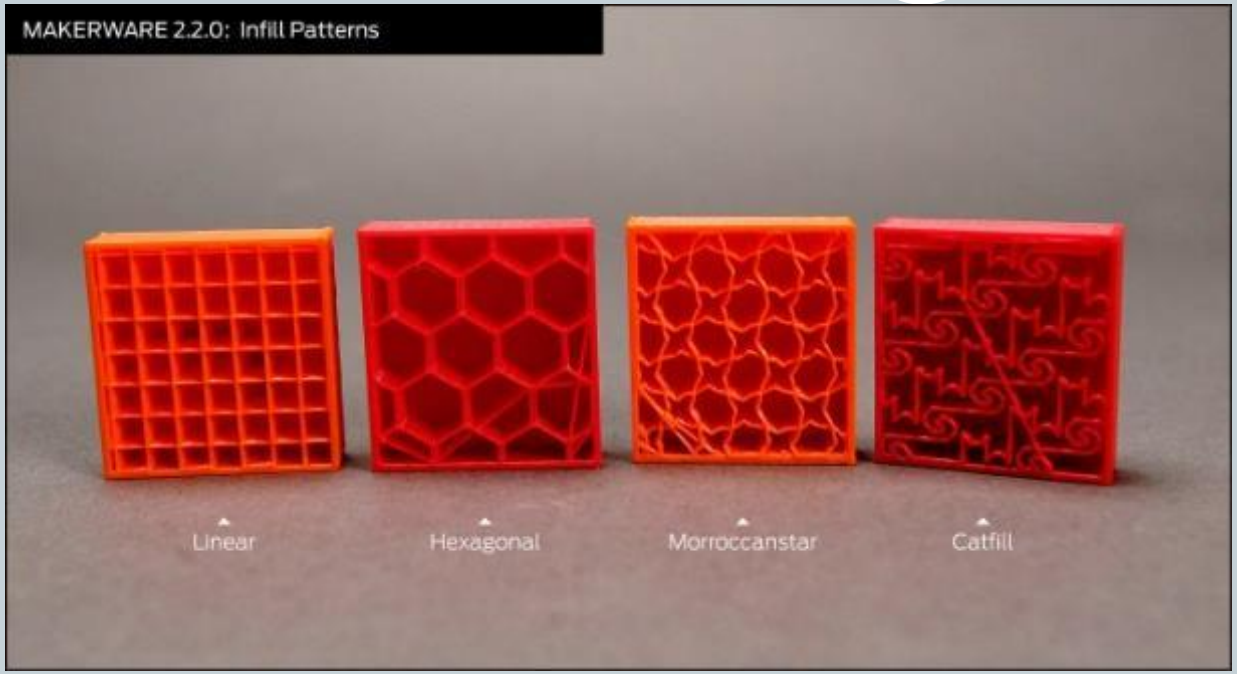




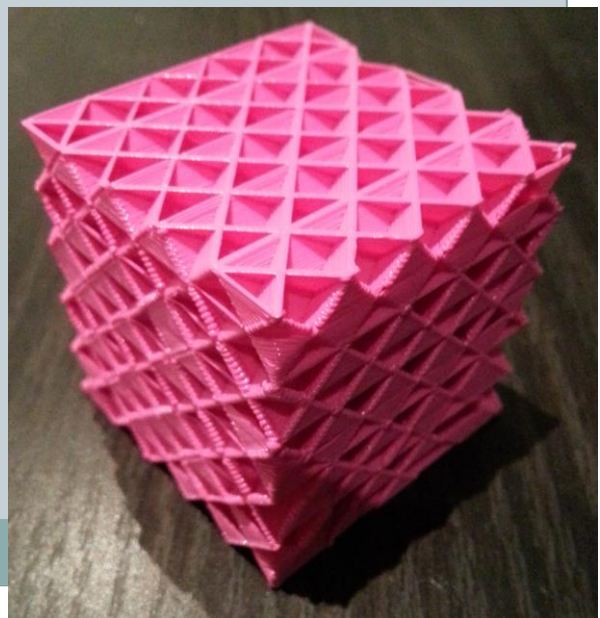
Toolpath Generation



Infill



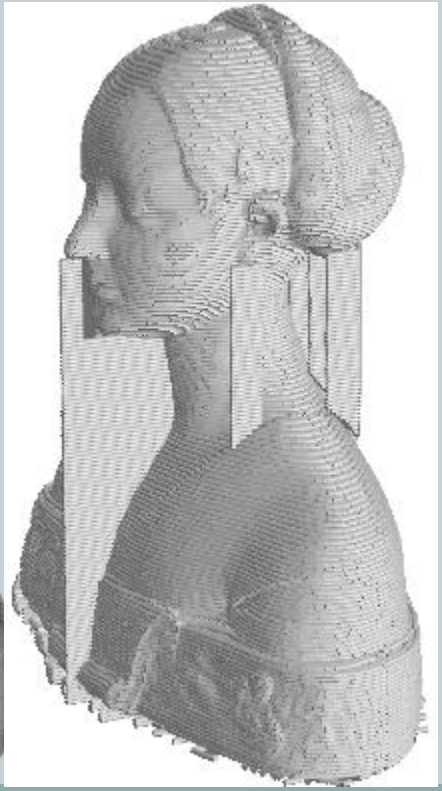
Objective: save material inside the object volume
(and preserve strength)



Support Structures

Deposited material is not self supporting!

- Automatic support generation done by most sofware tools
- Supports must be manually removed
- Some FDM's use a different support material (soluble)
- **In general:**
  FDM and SLA need supports!



Support Structures

[Dumas et al. 2014]

[MakerWare software]

[Vanek et al. 2014]

[Autodesk MeshMixer]

Problems

- Overhangs

Layer by layer building has problems when geoemtry has outstanding parts, steep surfaces, undercuts

- Temperature

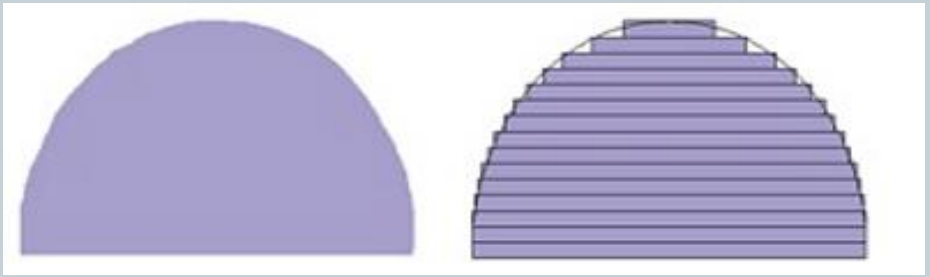
Plastic shrinks when cooling, curling/cracking the object. Too low temperature will not stick, too high will “bubble”

- Details/thickness

Even if the resolution of printer should handle them, most small details will disappear

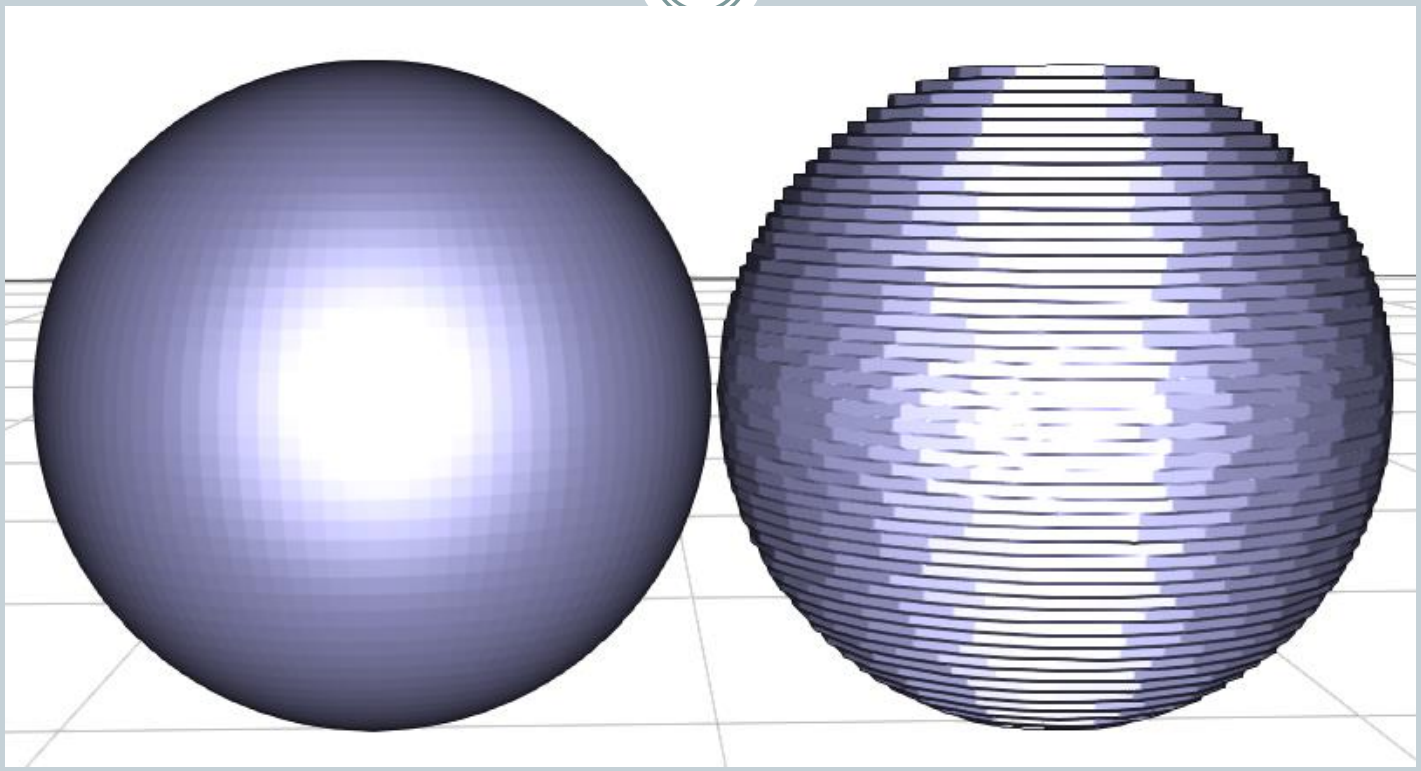
Slicing

Layering is unavoidable



The precision is different between <X,Y> and <Z> axis

Slicing



Lower layer thickness => Higher quality => Higher printing time

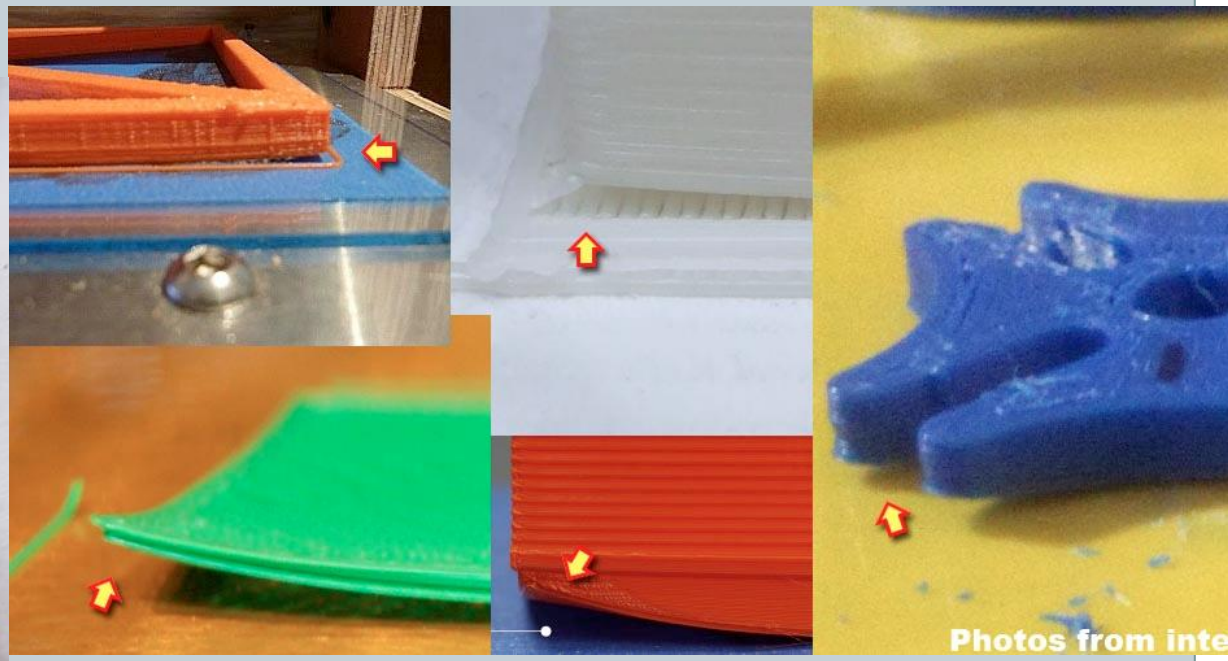
- 0.4 mm -> 1h
- 0.2 mm -> 3h
- …

Problems

- Overhangs

Problems

- Temperature



Not for home

We already saw 2 technologies not good for home/desktop printing…

- StereoLithography

- Powder printer

They are not the only ones…

All of them, however, are generally available through servicing…

Other technologies

Paper printers

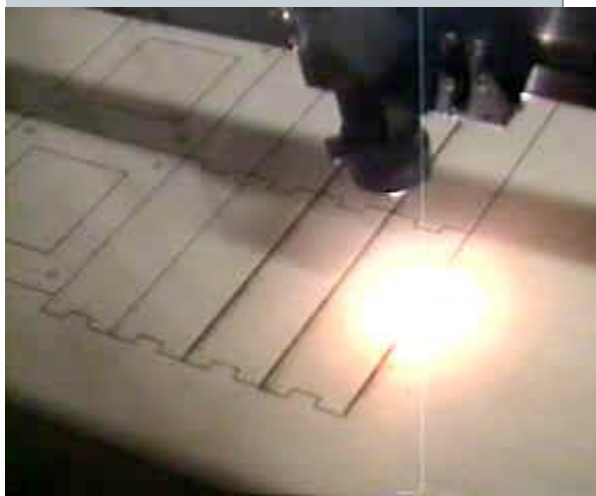
A sheet of paper at a time is cut, color printed and glued to the underlying one.

Good, solid results, no problem with overhangs, colored output, wastes a lot of material, but is fully recyclable

Other technologies

Laser cutter

Not strictly 3D printing, but still in the family.. 2D technique, but can be used for 3d objects



Other technologies

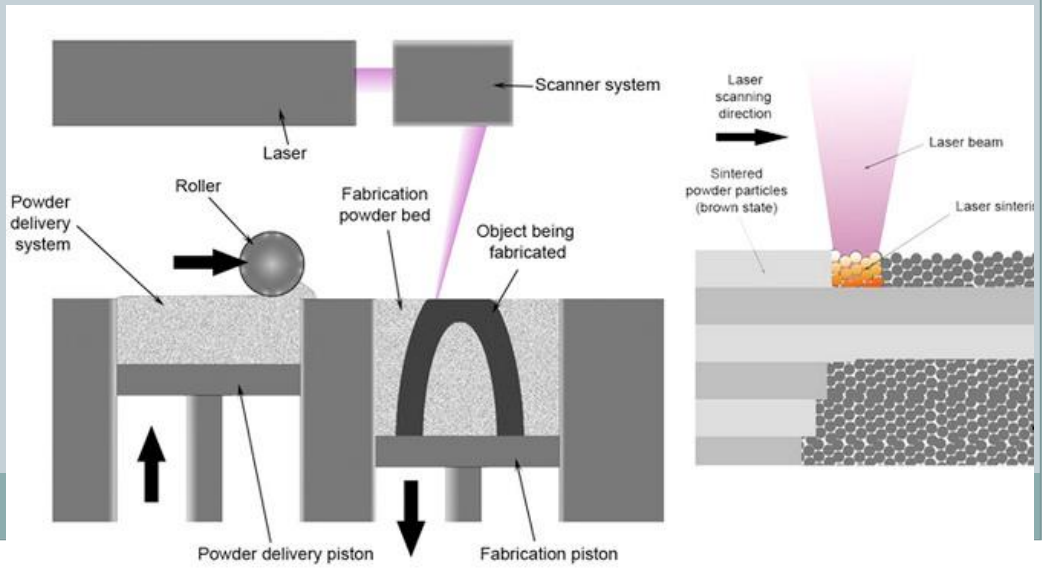
Ceramic printers

The printer works more or less like a FF plastic printer, but deposit CLAY, that is then fired in a kiln

Other technologies

METAL printers

The printer works more or less like a FF plastic printer, but deposit metal powder+resin, that is then fired in a kiln… OR a porouse substrate, which is then infiltrated with molten metal... OR it works like the powder printer, but the top layer is fused on the underlying one (see next slide).



Other technologies

SINTERING printers

Metals, plastics, hybrid materials… a laser “almost” melt a layer of material on top of another

And so on…

Printing using many kind of **resins**

Sugar/**chocolate**/**food** printing

Gold/**Silver** printing

In most case, however, they use a variant of one of these techniques…

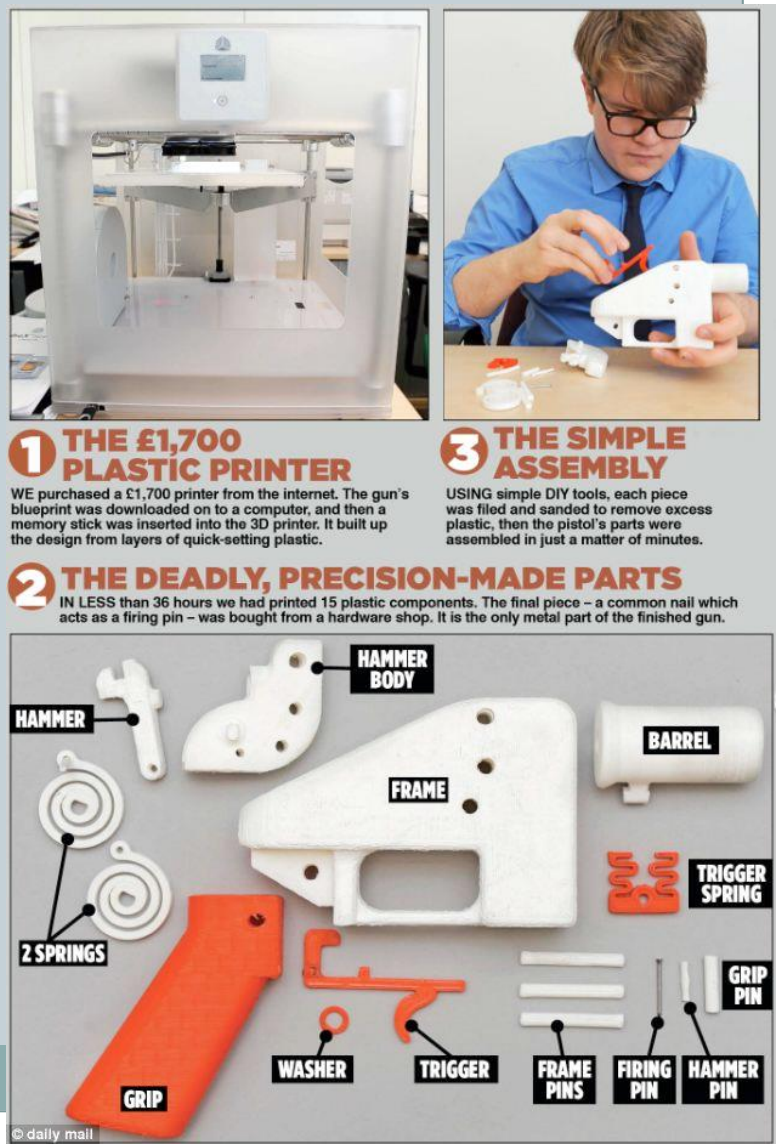
Controversy

Despite all the good things 3D printer can do, one thing was all over the newspapers last year:

THE 3D PRINTED GUN

Mostly, it was media stunt AND a Provocation of makers…

Anyone with a drill press / lathe may build a gun (much better than this one)



Things to see

The internet is full of resources for people interested in 3D printing, I will try to point out some basic resources lesson by lesson…

- RepRapWiki

  http://reprap.org/wiki/RepRap/it

- Make magazine

  http://makezine.com/

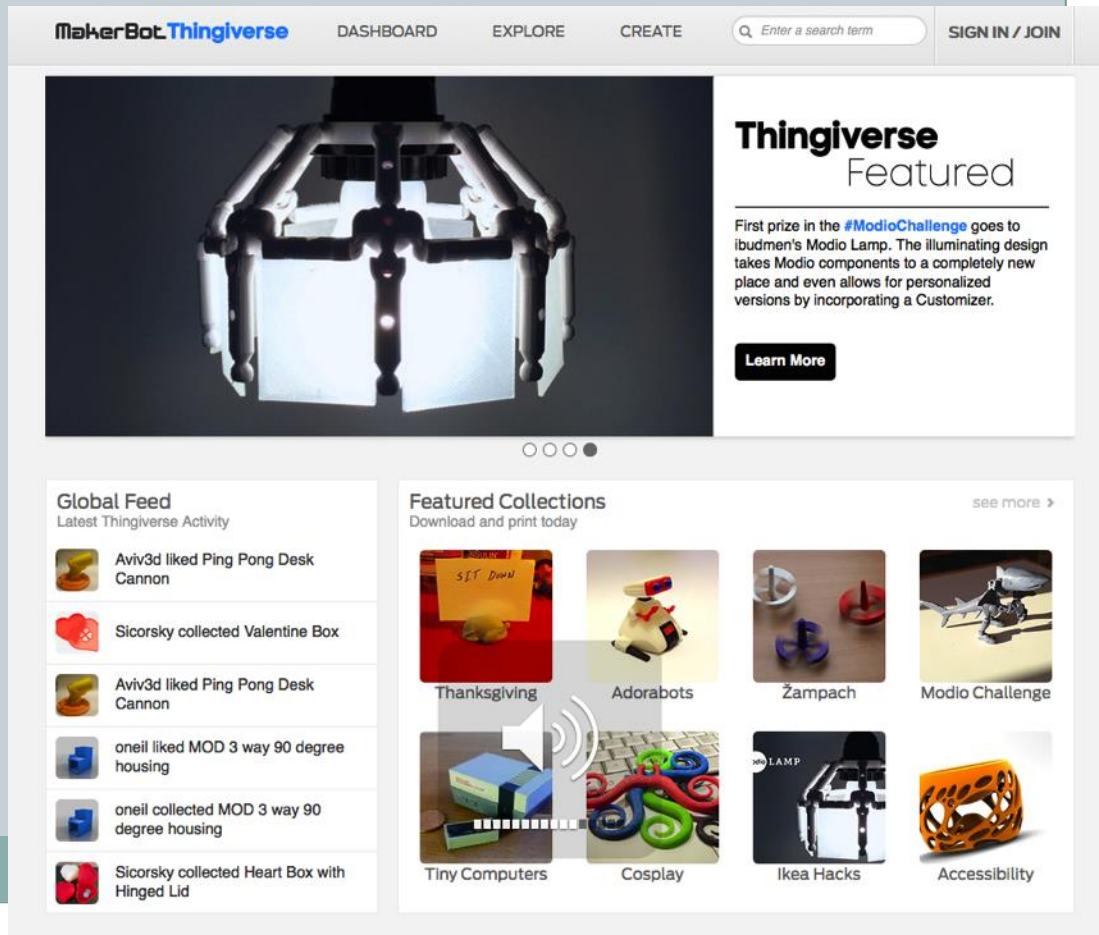
- Instructables

  http://www.instructables.com/

Thingverse

http://www.thingverse.com/

Free repository of printable objects, great resource for ideas, advices on printing, examples, reviews

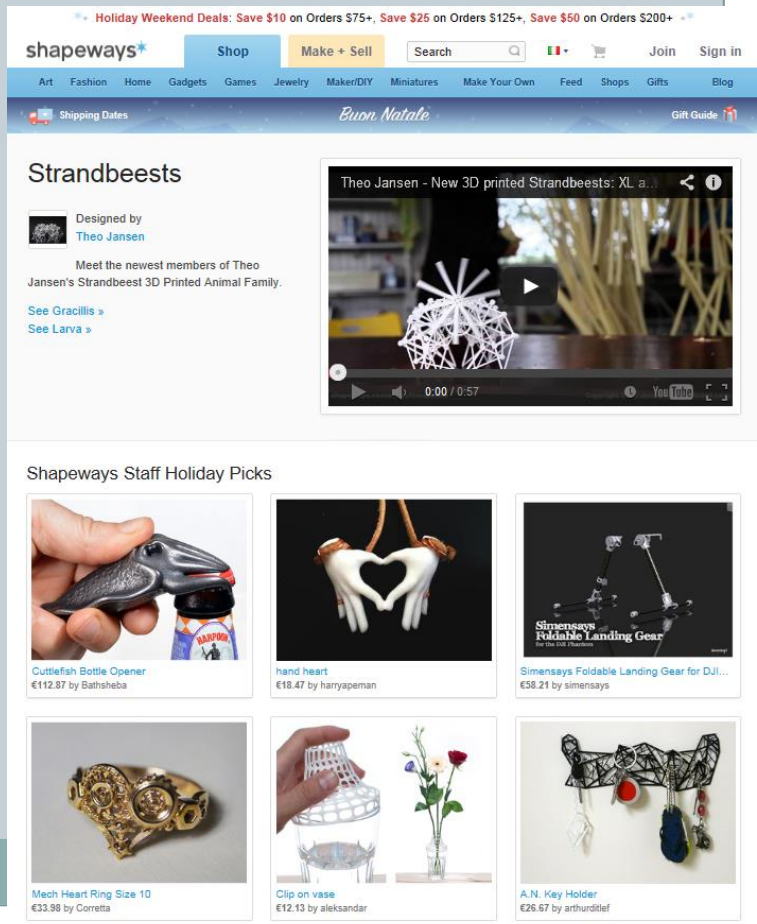


Shapeways

http://www.shapeways.com/

Online service for 3D printing… you upload the model, choose the material, and order it

Not super cheap, but fast and reliable



What about subtractive ?

Require much “harder” hardware, and it is not usable in a desktop environment. May go larger in size, but this require even costlier hardware

However, it is still widely used… the advantage is that it is possible to use different material… e.g. it is possible to carve STONE to replicate shape & material of a statue in the Cultural Heritage field, or metal for industrial applications

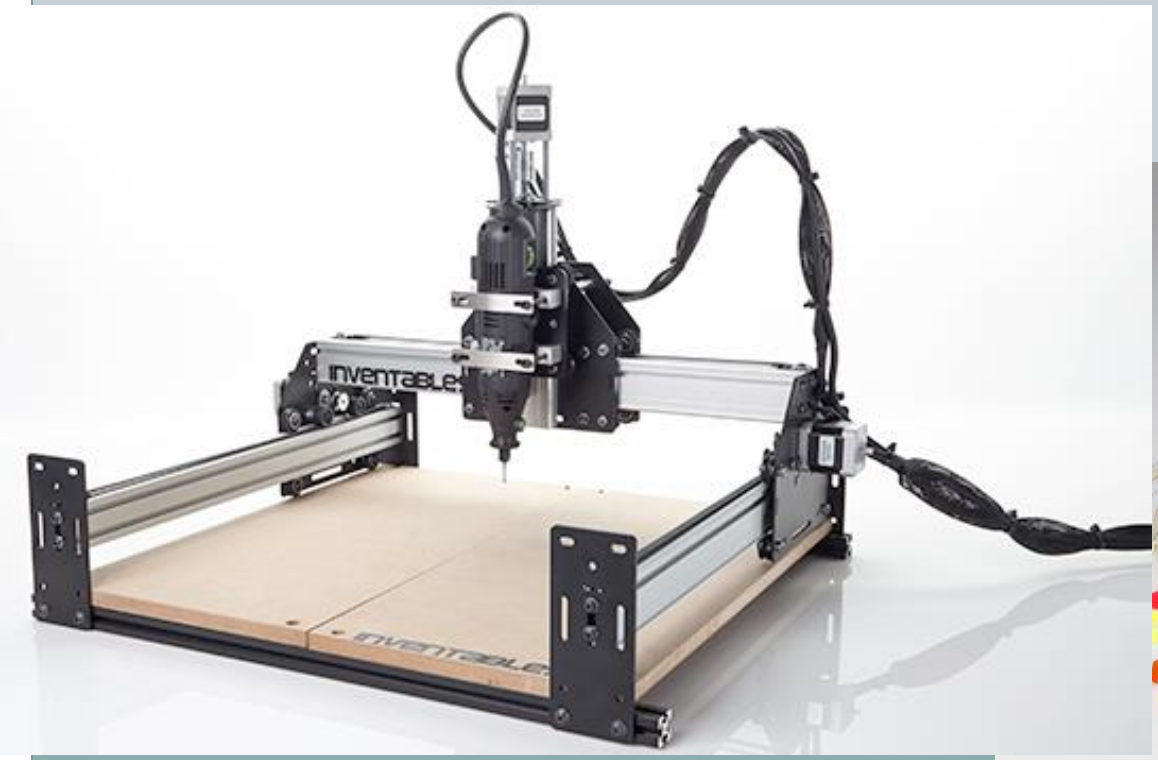
Robot sculpting

You will be surprised to know how many sculpting robots are active in the Carrara area… most of them just for the initial steps, but some for the complete sculpting process…

Robot sculpting

At home ?

Some cheap do-it-yourself CNC, a couple of commercial products… however, still much more messy than FF printing



Question Time

GRAZIE PER L'ATTENZIONE

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