



Aalto University  
Media Factory

# Digital\_Fabrication\_Studio.08

## 3D Printing – from bits to atoms

Massimo Menichinelli

massimo.menichinelli@aalto.fi

@openp2pdesign

<http://www.slideshare.net/openp2pdesign>



16.10.2012



Aalto University  
Media Factory

# Today:

- \* 3D printing: technologies
- \* 3D printing: examples
- \* Design techniques



Aalto University  
Media Factory

01.

# 3D printing technologies: atoms from bits

# Technologies: 3D printing



Refers to object made using ink jet technology in 3 dimensions by layering powder and binding it with pigmented glue.

Source: <http://replicatorinc.com/blog/2009/02/4-types-of-3d-printing/>  
<http://youtu.be/7QP73uTJApw>

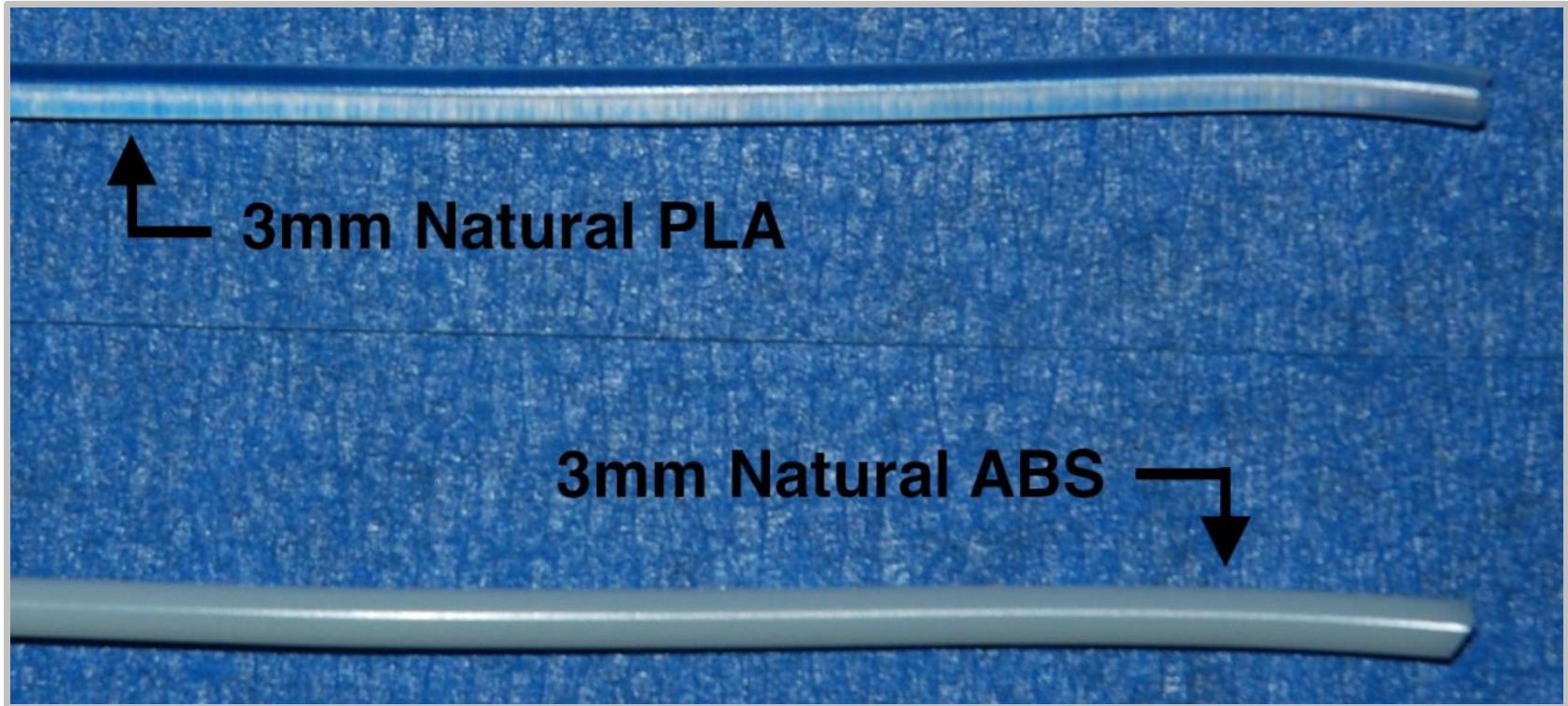
# Technologies: Fused Deposition Modeling



Fused Deposition Modeling (FDM) creates models by heating and extruding a filament of plastic material.

Source: <http://replicatorinc.com/blog/2009/02/4-types-of-3d-printing/>  
<http://youtu.be/h8XJUqHXgls>

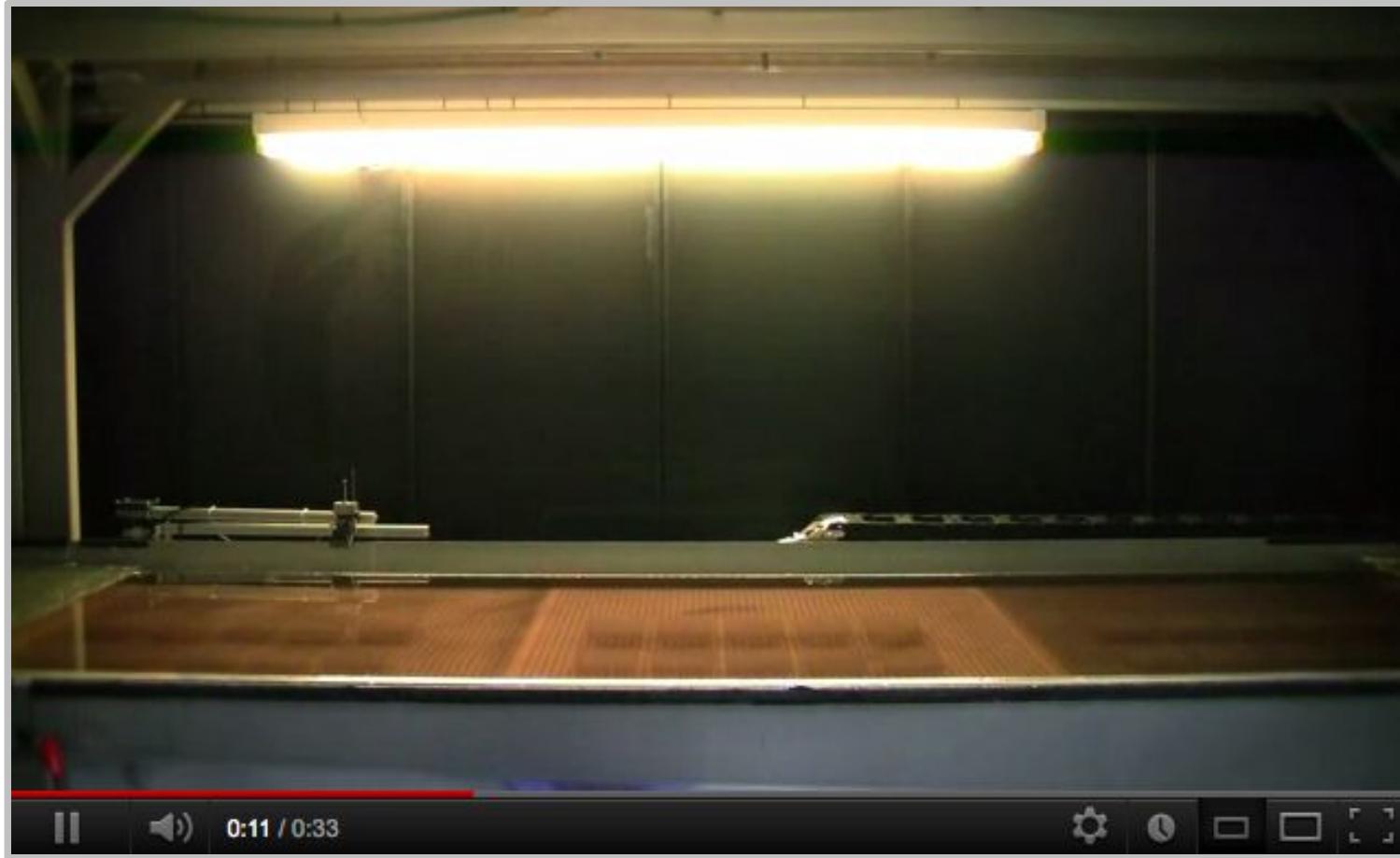
# Technologies: materials for FDM



Most of the 3D Printing community uses either ABS or PLA in either 3mm or 1.75mm diameters.

Source: <http://www.protoparadigm.com/2011/11/filament-tolerances-and-print-quality/>

# Technologies: Stereolithography



Stereolithography produces models by tracing a beam of UV light over a photosensitive pool of liquid. Over time the part is lowered into the bath.

Source: <http://replicatorinc.com/blog/2009/02/4-types-of-3d-printing/>  
<http://youtu.be/ygHVVKKkJWI>

# Technologies: Stereolithography



Stereolithography produces models by tracing a beam of UV light over a photosensitive pool of liquid. Over time the part is lowered into the bath.

Source: <http://replicatorinc.com/blog/2009/02/4-types-of-3d-printing/>  
<http://youtu.be/sn0Erp0P5Xk>

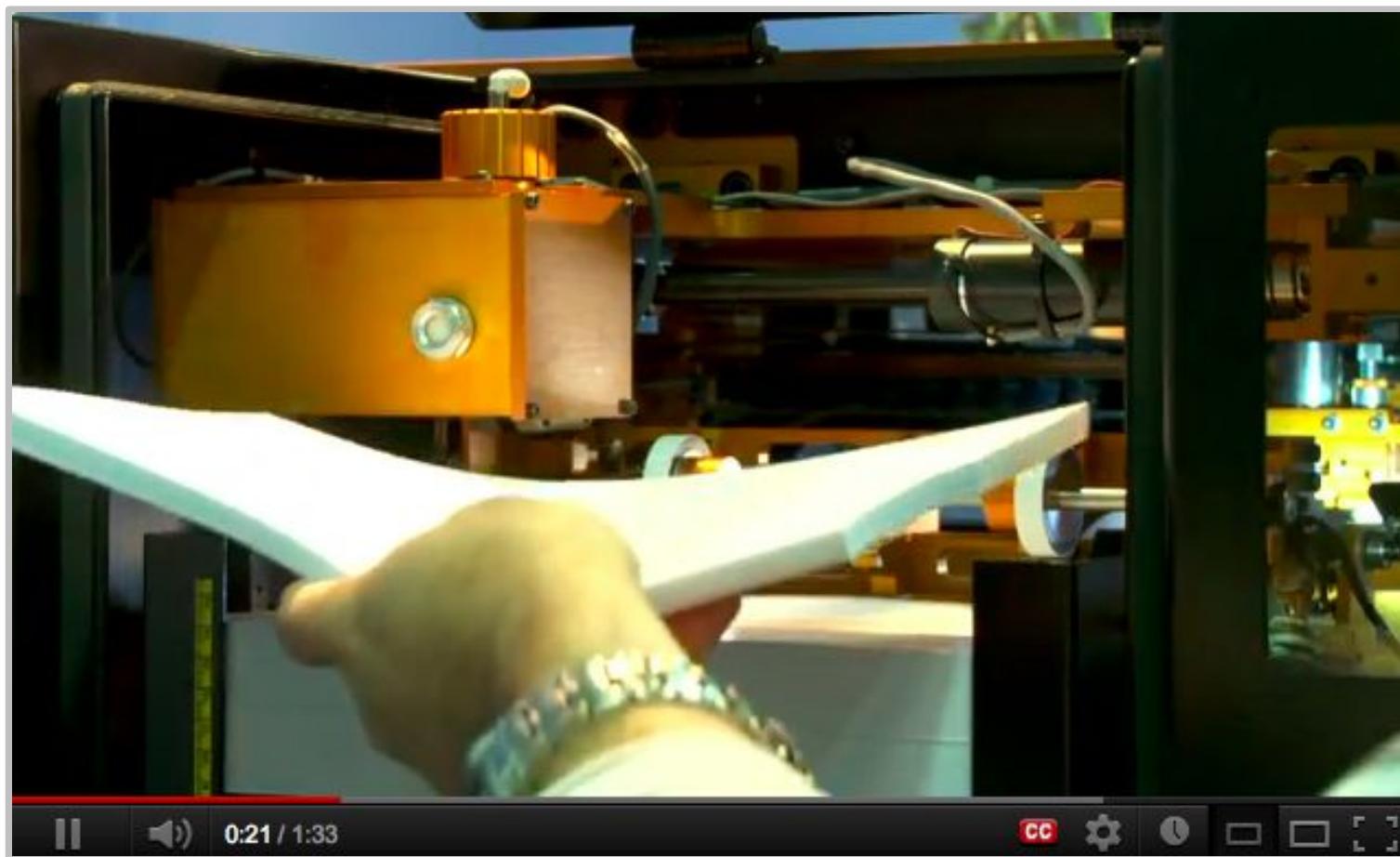
# Technologies: Selective Laser Sintering



Selective Laser Sintering (SLS) is similar to stereolithography replacing the UV light with a laser and a vat of liquid with a powdered base.

Source: <http://replicatorinc.com/blog/2009/02/4-types-of-3d-printing/>  
[http://youtu.be/lCOuVO\\_uT0s](http://youtu.be/lCOuVO_uT0s)

# Technologies: Laminated Object Manufacturing



Laminated Object Manufacturing (LOM) machines cut and glue thousands of sheets of material together to form solids, sometimes with standard A4 paper.

Source: <http://replicatorinc.com/blog/2009/02/4-types-of-3d-printing/>  
<http://youtu.be/FjxI2HszHzo>

# Technologies: Laminated Object Manufacturing



---

Laminated Object Manufacturing (LOM) machines cut and glue thousands of sheets of material together to form solids, sometimes with standard A4 paper.

Source: <http://replicatorinc.com/blog/2009/02/4-types-of-3d-printing/>  
<http://www.mcortechnologies.com/gallery>

# Technologies: Electron Beam Melting



Electron Beam Melting (EBM) is similar to SLS except the process is far more exact and capable of producing implant grade parts to be used in orthopedic surgery.

Source: <http://replicatorinc.com/blog/2009/02/4-types-of-3d-printing/>  
<http://youtu.be/E7--ZWPVVdQ>

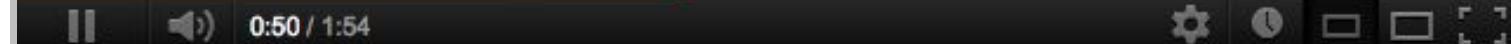
# 3D Metal printing



Now it is possible to print your model in stainless steel on Shapeways! The material will be finished in a shining stainless steel look and costs \$10 / cm<sup>3</sup>.

Source: <http://youtu.be/B9V0wqt0glg>  
[http://www.shapeways.com/themes/stainless\\_steel\\_3dprinting\\_gallery](http://www.shapeways.com/themes/stainless_steel_3dprinting_gallery)

# 3D Glass printing

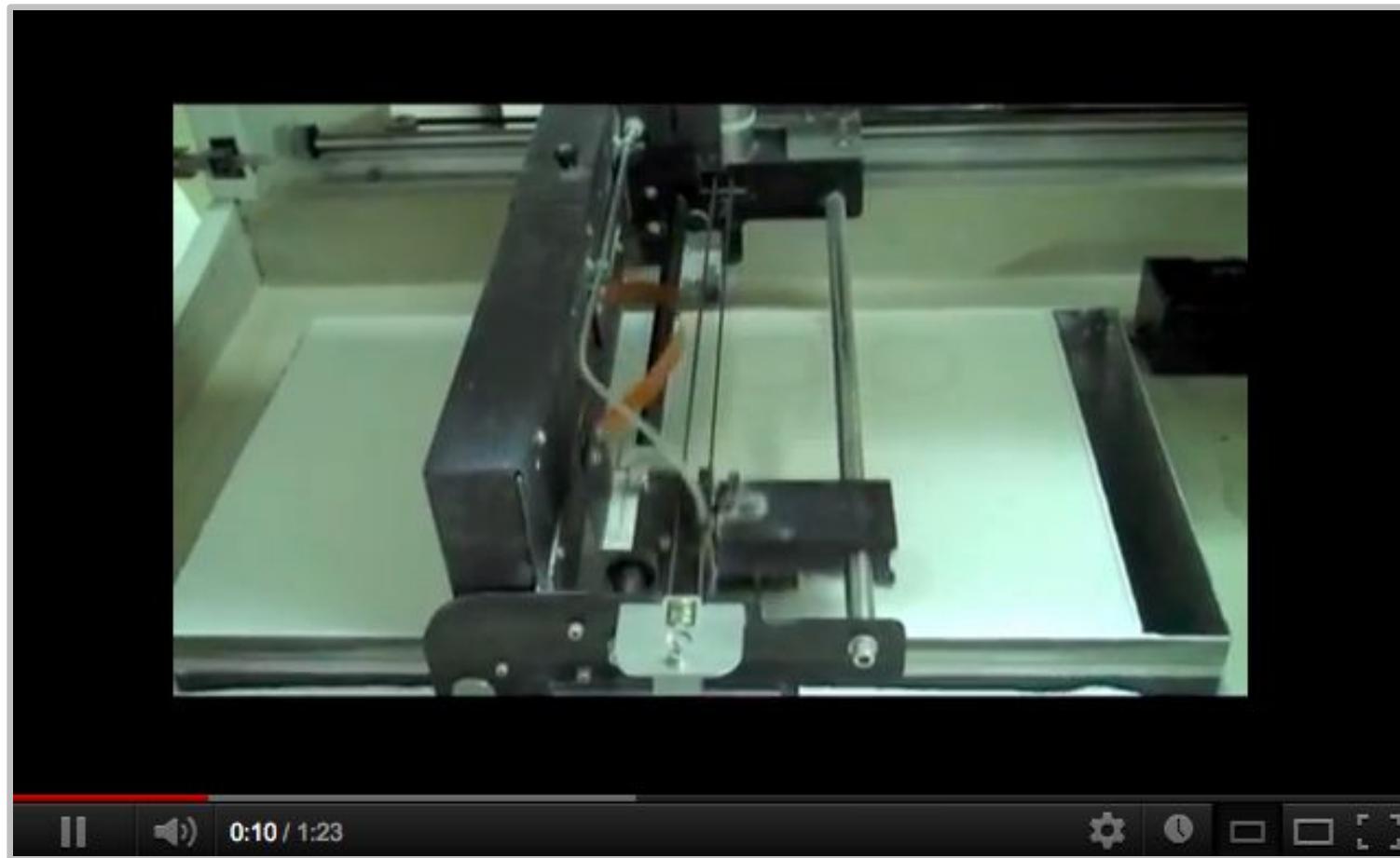


The material is porous, opaque and fragile and made from recycled soda-lime glass, the fine glass powder is glued together with a binder and then sintered.

Source: <http://youtu.be/BtK-Hqd6Q2I>

[http://www.shapeways.com/materials/milky\\_white\\_matte\\_glass](http://www.shapeways.com/materials/milky_white_matte_glass)

# 3D Ceramics printing



Material properties are the same as standard ceramics. Fine ceramic powder bound together with binder, fired, glazed with lead-free, non-toxic gloss finish.

Source: <http://youtu.be/zZU701BHfyo>  
<http://www.shapeways.com/materials/ceramics>

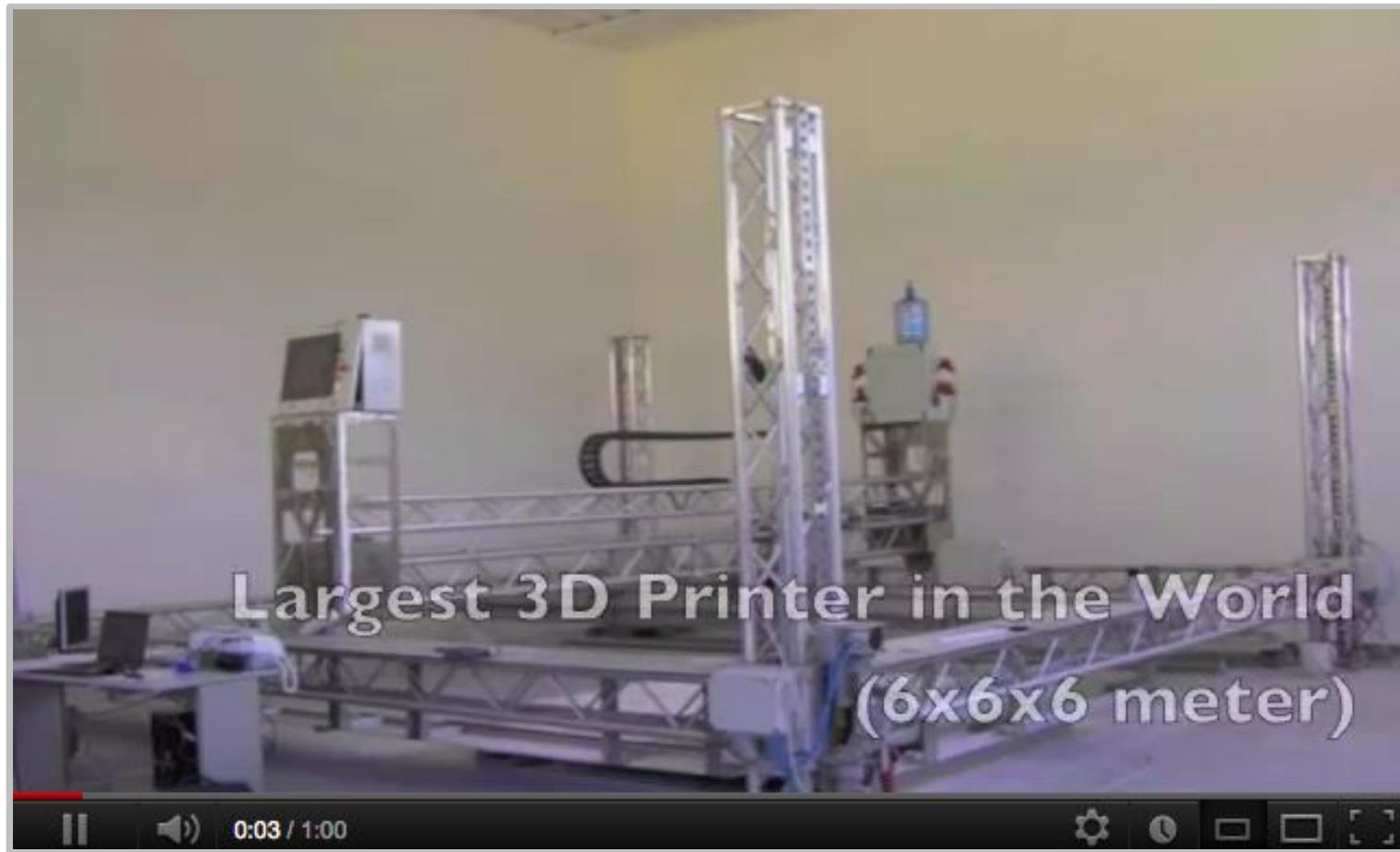
# Big size 3D printing: Endless chair



Printing an Endless Chair from recycled refrigerators.  
Design by Dirk vander Kooij.

Source: <http://youtu.be/FvRTHynk9KA>  
<http://www.dirkvanderkooij.nl/en>

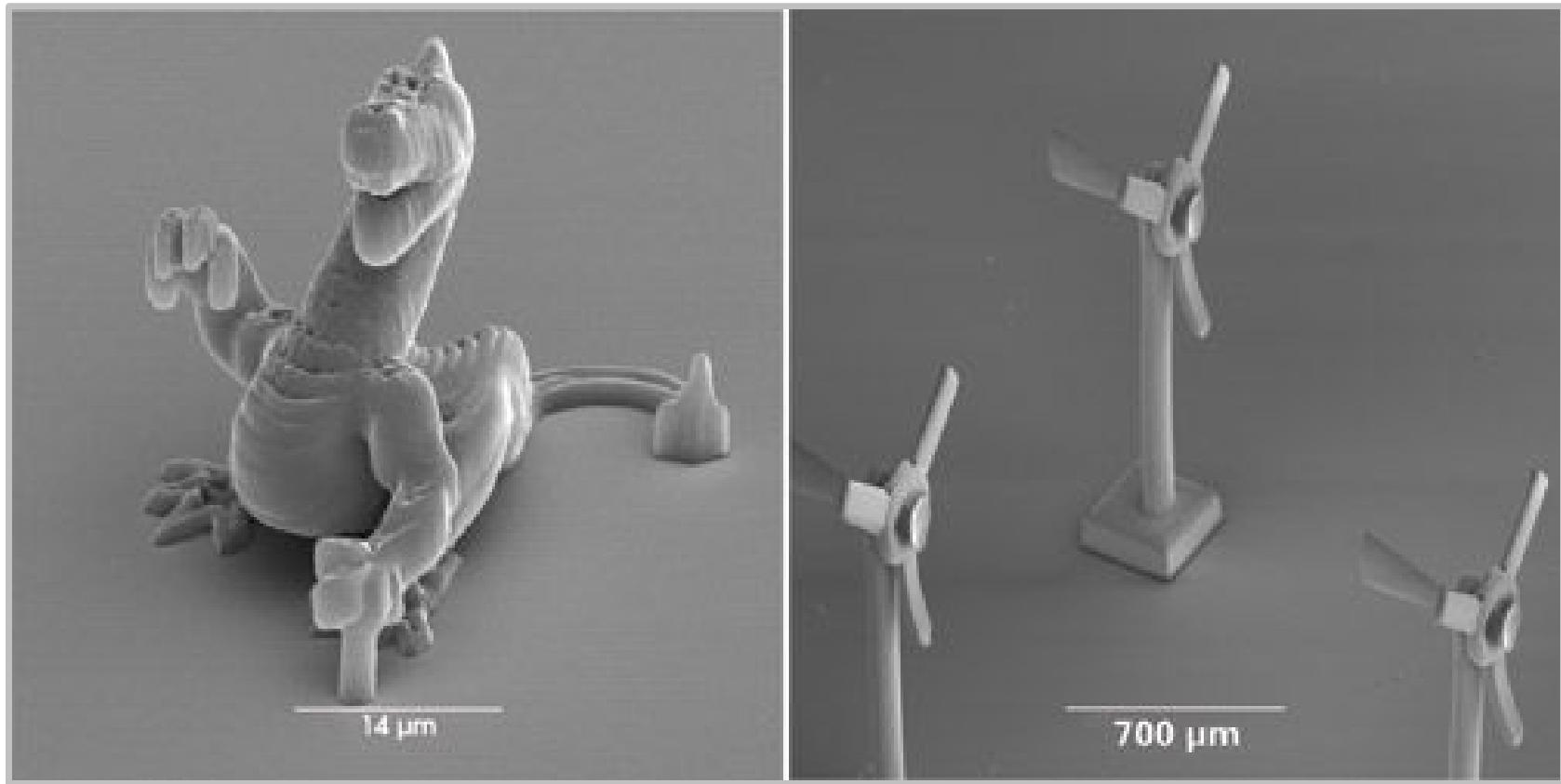
# Big size 3D printing: D-Shape



D-Shape is a new robotic building system using new materials to create superior stone-like structures.

Source: <http://youtu.be/HBxx8XTpDZ4>  
<http://d-shape.com/>

# Small size 3D printing: 2 photons polymerization



A promising 3D microfabrication method that has recently attracted considerable attention is based on two-photon polymerization with ultrashort laser pulses.

Source: <http://www.photonics.com/Article.aspx?AID=26907>

# Bio 3D Printing



A new tissue engineering technology now has the ability to arrange culture cells in three dimensions. It is now possible to manufacture tissue in demand.

Source: <http://youtu.be/YOnIxcc0DW8>

# Bio 3D Printing: Organovo

The screenshot shows the Organovo website homepage. At the top left is the Organovo logo. To its right is a search bar. Below the header, the tagline "Tissue on demand." is prominently displayed. A paragraph below it explains that Organovo's NovoGen Bioprinting platform creates human tissues from any cell source, addressing urgent needs in biological research. Two news items are listed: "April 25, 2012: Organovo Expands Management Team, Announces Promotion" and "April 2, 2012: Organovo Reports 2011 Financial Results". To the right of the main content area, there is a graphic titled "tr50 The 50 Most Innovative Companies in 2012" showing Organovo's position in the biomedicine sector. Below this is a banner stating "Named to MIT Technology Review's List of Most Innovative Companies". The footer contains links for About, Products, Science, Newsroom, Investors, and Contact.

**organovo™**

Search

## Tissue on demand.

Organovo's powerful NovoGen Bioprinting platform creates human tissues starting with any cell source. From disease models to tissue creation, bioprinting solves urgent needs in biological research.

April 25, 2012: [Organovo Expands Management Team, Announces Promotion](#)

April 2, 2012: [Organovo Reports 2011 Financial Results](#)

**tr50** The 50 Most Innovative Companies in 2012

Organovo BIOMEDICINE

Named to MIT Technology Review's List of Most Innovative Companies

**ABOUT**  
Our Management  
Careers

**PRODUCTS**  
NovoGen MMX Bioprinter™  
Support

**SCIENCE**  
Publications  
Collaborations  
Links

**NEWSROOM**  
Overview  
Press Releases  
Media Coverage  
Media Contact

**INVESTORS**

**CONTACT**

Organovo is focused on delivering breakthrough three-dimensional biology capabilities to create tissue on demand for research and surgical applications.

Source: <http://www.organovo.com/>

# Bio 3D Printing: Organovo

A screenshot of the Organovo website's products page. The header features the Organovo logo and a search bar. Below the header is a navigation menu with links for About, Products, Science, Newsroom, Investors, and Contact. The main content area has a dark blue background with the word "products" in white. To the right of the text is a photograph of the NovoGen MMX Bioprinter machine. On the left side of the main content area, there is a sidebar with links for Overview, NovoGen MMX Bioprinter™, and Support. The NovoGen MMX Bioprinter™ section contains a sub-headline "Human biology, in vitro convenience.", a detailed description of the machine's capabilities, and another photograph of the bioprinter next to a computer monitor displaying software interface.

The NovoGen MMX Bioprinter™ is a novel hardware and software platform at the forefront of bioprinting research and development.

Source: <http://www.organovo.com/products/novogen-mmx-bioprinter>

# Drug 3D Printing

The image is a screenshot of a news article from Gizmodo UK. At the top, the 'GIZMODO' logo is displayed in a stylized blue font with 'UK' in smaller letters to its right. Below the logo is a collection of various pharmaceutical drugs, including several large, colorful capsules and numerous smaller tablets in different colors like yellow, green, and brown. The article is categorized under 'SCIENCE'. The title of the article is 'Who Needs a Pharmacy When You Can Just Print-Out Your Own Drugs at Home?'. The date of publication is April 19, 2012, at 12:45pm. Social sharing icons for Google+ and Facebook are located at the bottom right of the article area.

Researchers from Scotland have made their own DIY 3D-printing drugstore and you'll be able to use them to print your own drugs right at your own home.

Source: <http://www.gizmodo.co.uk/2012/04/who-needs-a-pharmacy-when-you-can-just-print-out-your-own-drugs-at-home/>

# Food 3D Printing



Choc Creator, the world's first 3D chocolate printer was developed by a team of researchers at the University of Exeter and is now available to purchase.

Source: <http://laughingsquid.com/choc-creator-the-chocolate-3d-printer-is-now-available-to-purchase/>  
<http://youtu.be/r7xs-cHAt3I>

# Food 3D Printing

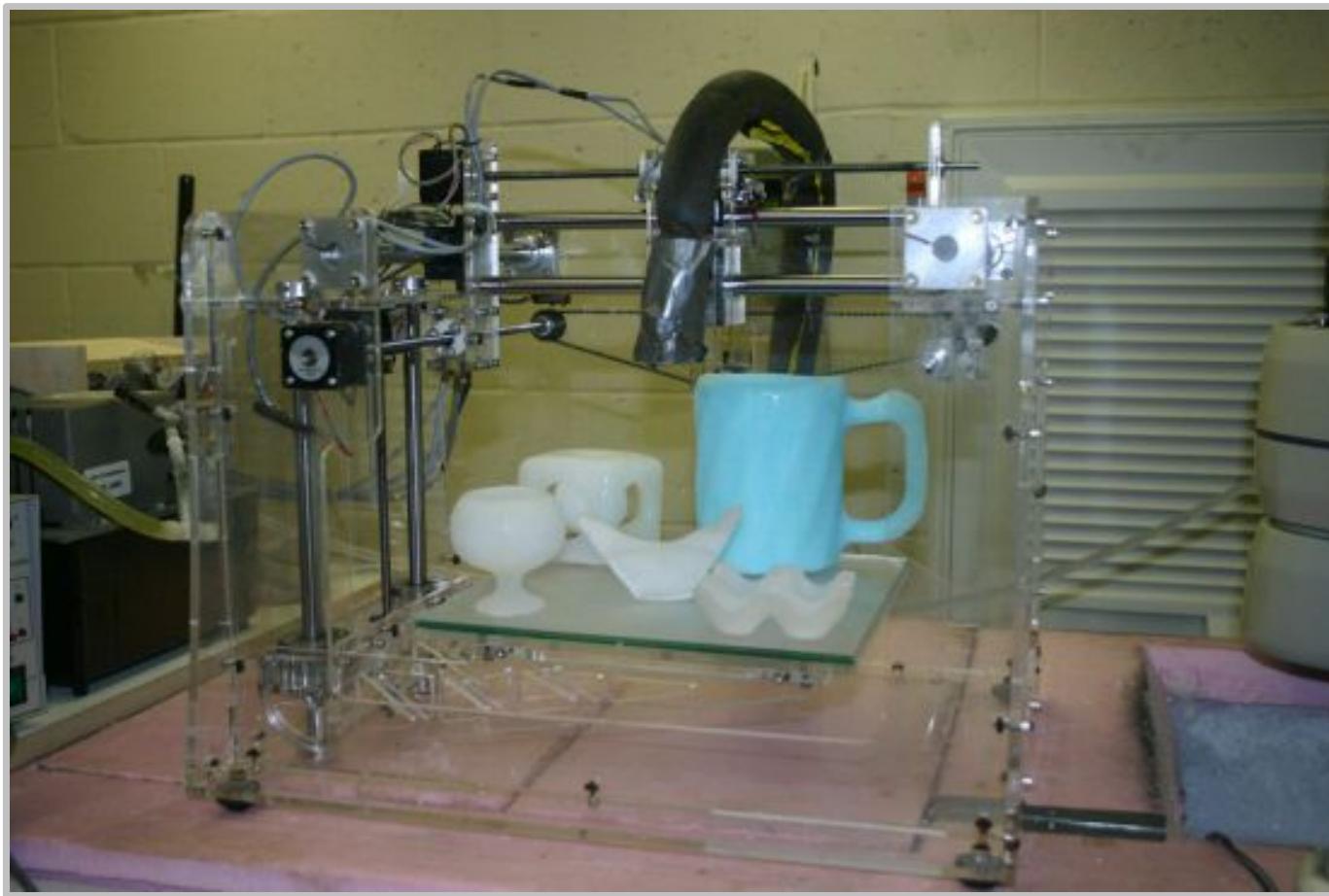


---

CandyFab is a machine that can make arbitrary 3D solid objects at low cost from a variety of low-melting point materials including pure sugar.

Source: <http://laughingsquid.com/choc-creator-the-chocolate-3d-printer-is-now-available-to-purchase/>  
<http://youtu.be/r7xs-cHAt3I>

# Ice 3D Printing



Pieter Sijpkes, a professor at McGill University, has discovered since cobbling together a machine that prints objects by building up ultrathin layers of ice.

Source: [http://www.wired.com/magazine/2011/12/st\\_3diceprinting/](http://www.wired.com/magazine/2011/12/st_3diceprinting/)  
<http://www.3ders.org/articles/20120103-3d-ice-printer.html>

# Recycle plastic for your FDM machine

KICKSTARTER Discover Start BLOG HELP SIGN UP LOG IN

## Filabot: Plastic Filament Maker

A Technology project in Milton, VT by Tyler McNaney · send message

PROJECT HOME UPDATES 14 BACKERS 156 COMMENTS 239



PLAY

156 BACKERS  
\$32,330 PLEDGED OF \$10,000 GOAL  
0 SECONDS TO GO

FUNDING SUCCESSFUL  
This project successfully raised its funding goal on January 23.

PLEDGE \$1 OR MORE  
41 BACKERS

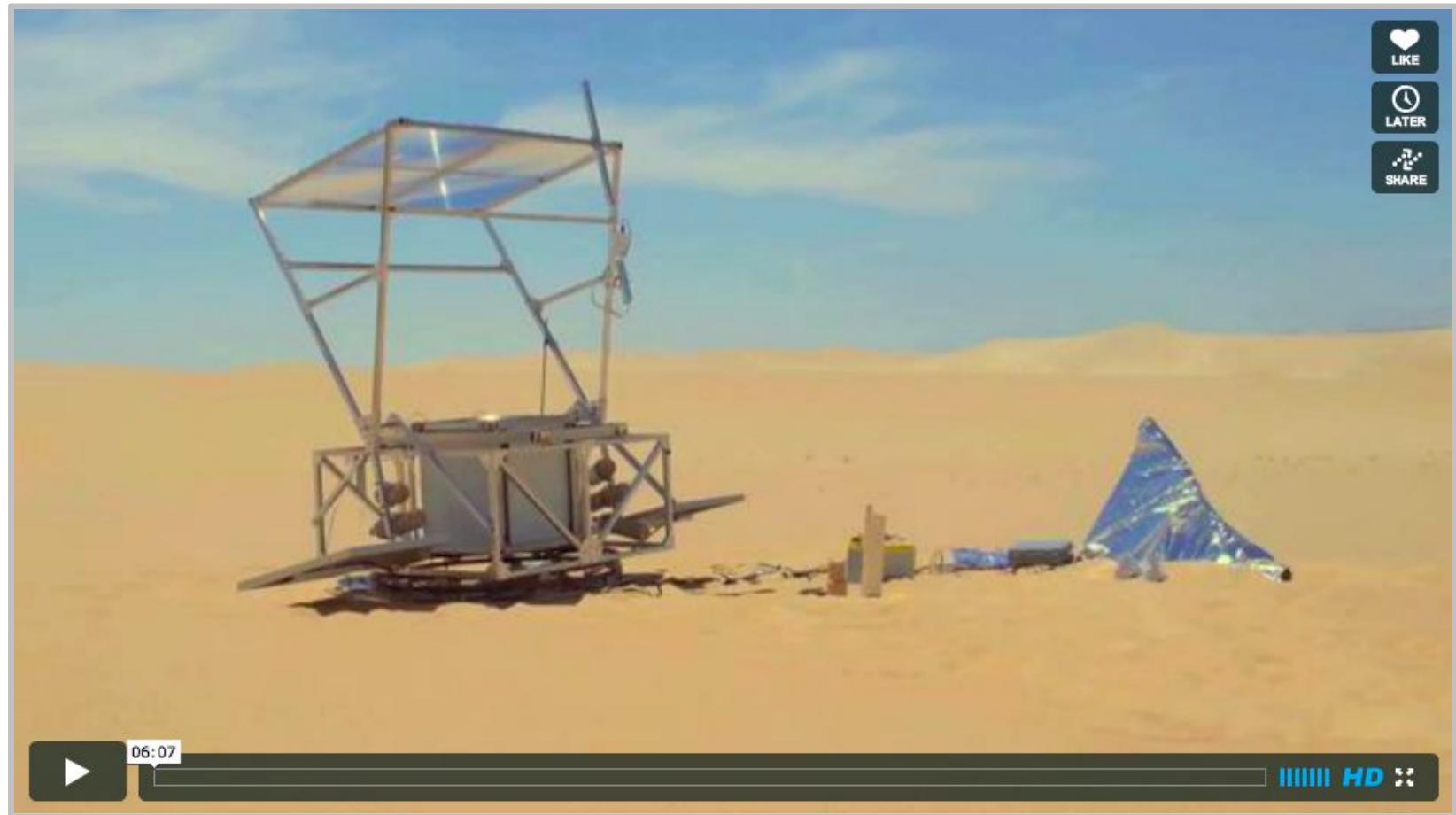
Like 243 people like this. Be the first of your friends.

Tweet Embed http://kck.st/uYHFdj

A 3D plastic extrusion system for mostly any type of recyclable plastic, to make usable 3D printing filament by grinding, melting, extruding the plastic filament.

Source: <http://www.kickstarter.com/projects/rocknail/filabot-plastic-filament-maker>

# Markus Kayser - Solar Sinter Project

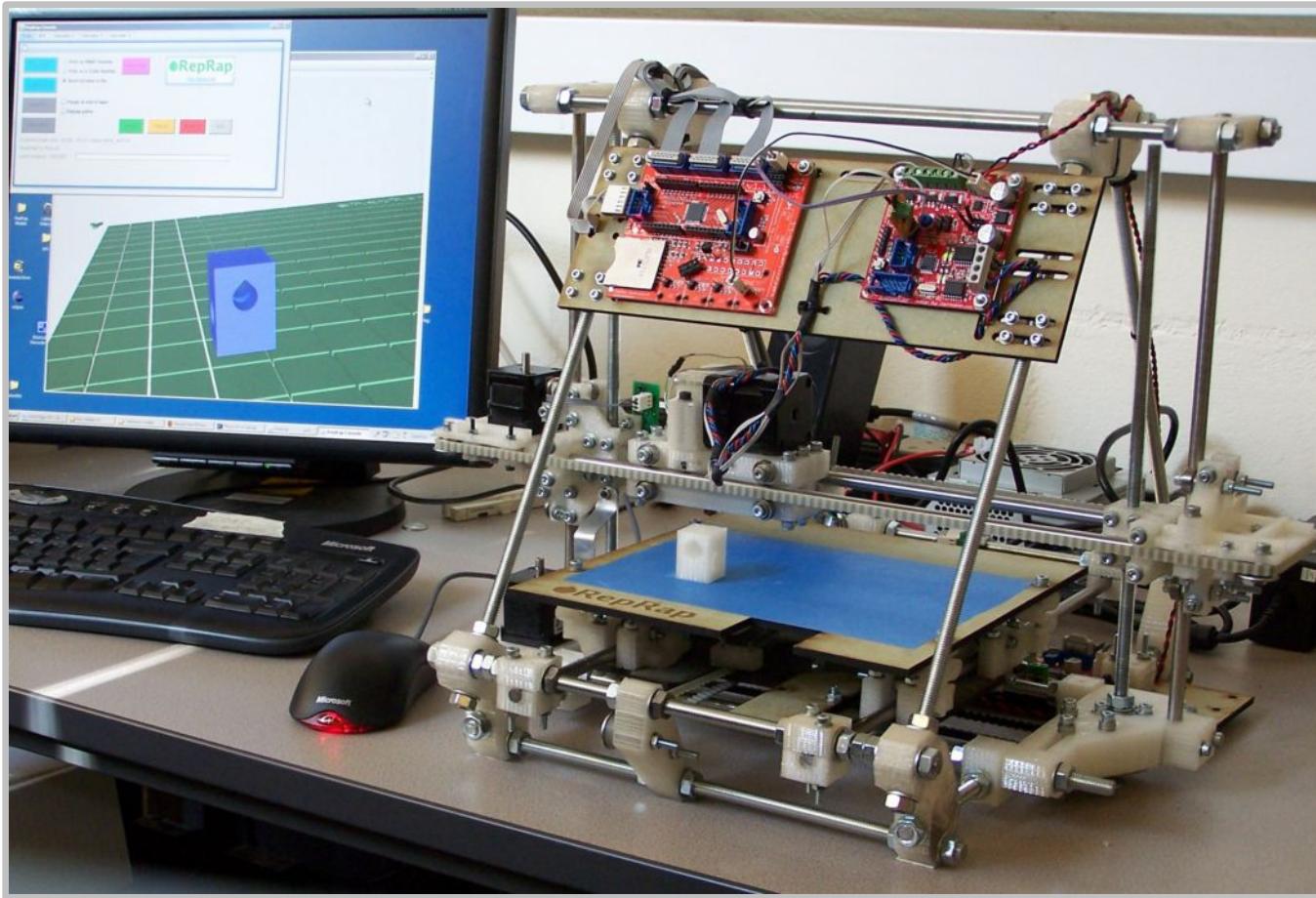


LIKE  
LATER  
SHARE

In this experiment sunlight and sand are used as raw energy and material to produce glass objects using a 3D printing process.

Source: <http://vimeo.com/25401444>

# Open Source 3D printers: RepRap

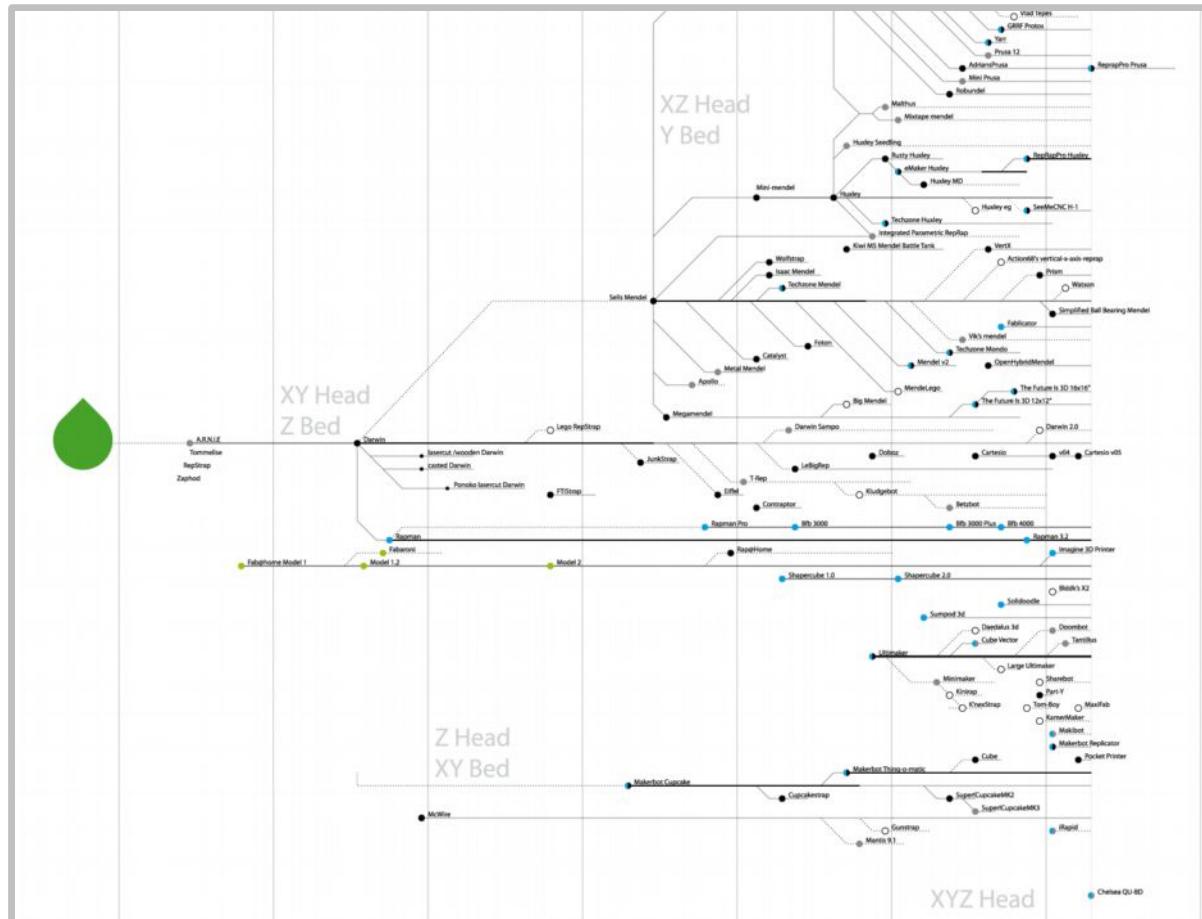


---

It's the second, improved version of RepRap: small enough to fit on your desk, but with a print volume large enough for you to make big things.

Source: <http://reprap.org/wiki/Mendel>

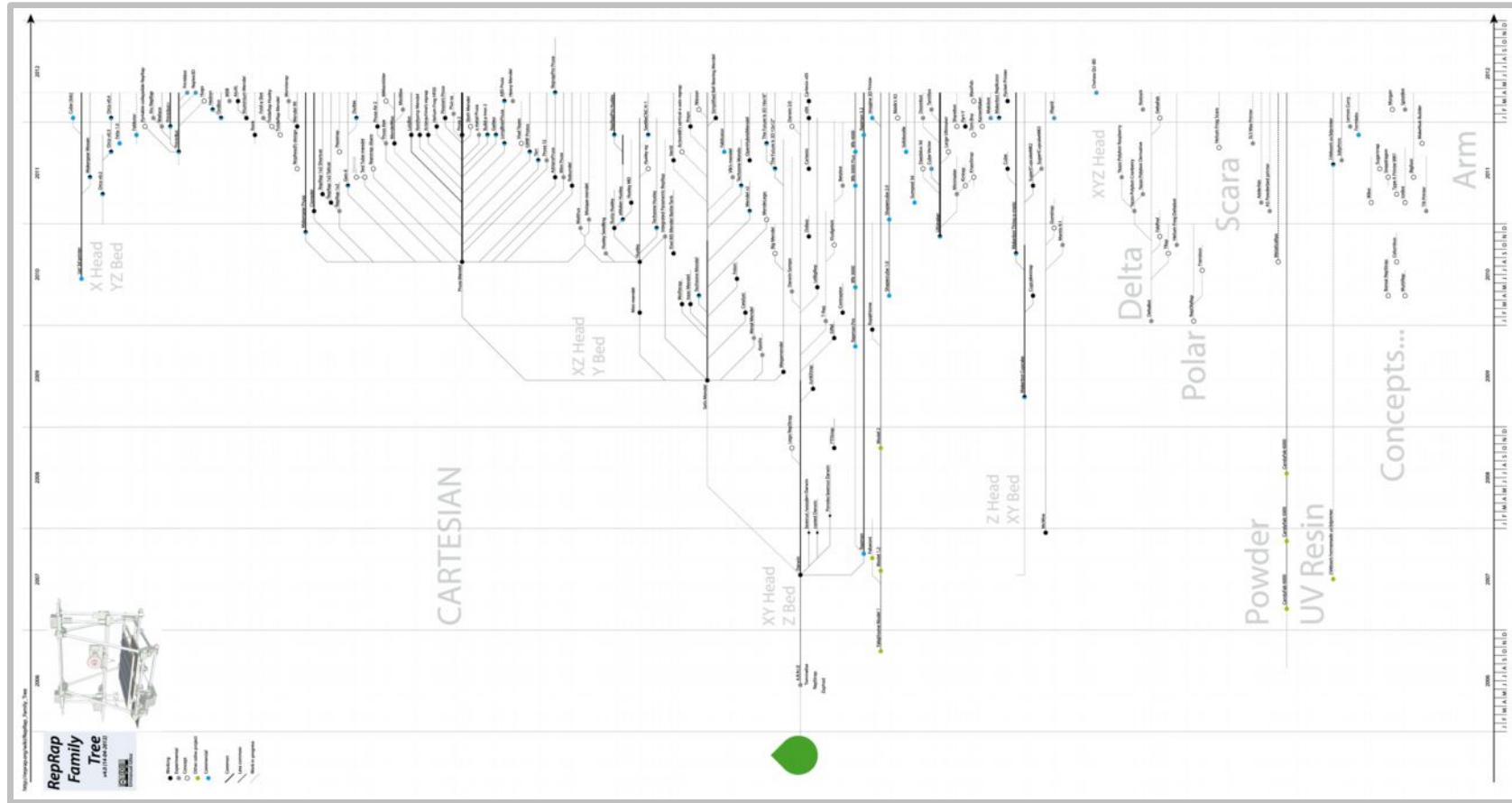
# Open Source 3D printers: RepRap



Again, the evolution of an open source project that's too big to fit into one slide...

Source: [http://reprap.org/wiki/RepRap\\_Family\\_Tree](http://reprap.org/wiki/RepRap_Family_Tree)

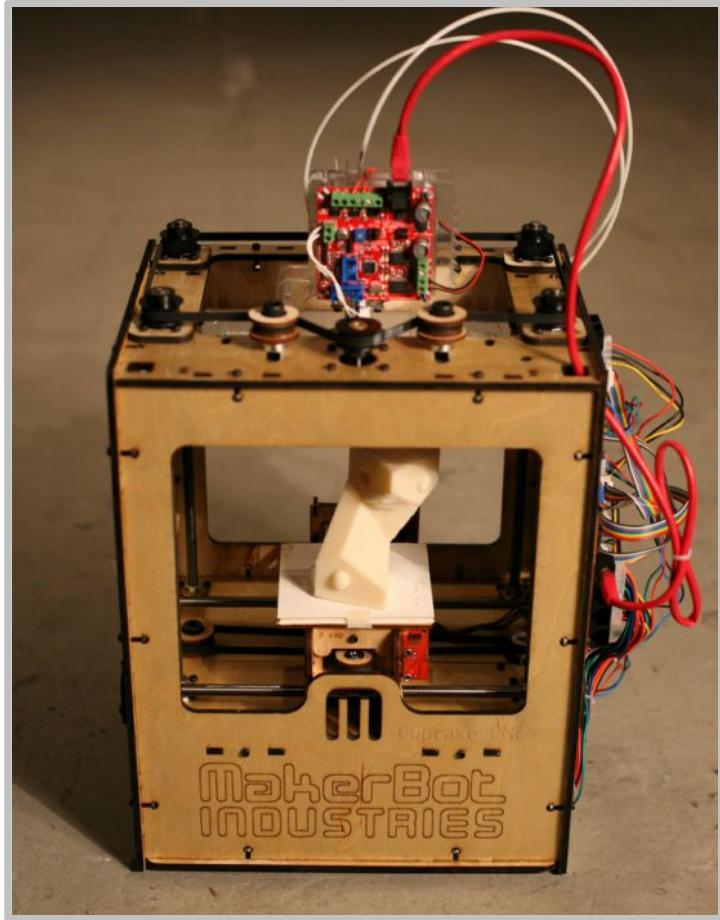
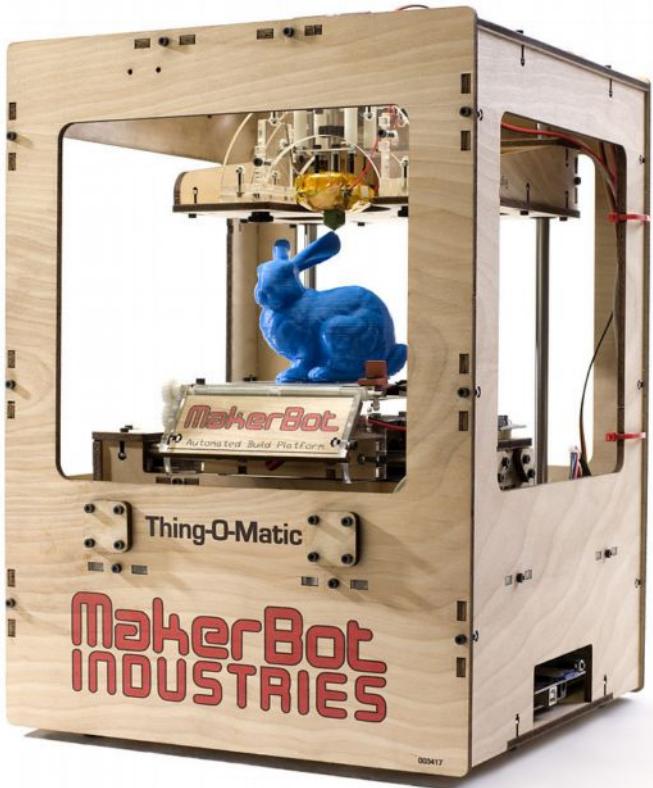
# Open Source 3D printers: RepRap



Again, the evolution of an open source project that's too big to fit into one slide...

Source: [http://reprap.org/wiki/RepRap\\_Family\\_Tree](http://reprap.org/wiki/RepRap_Family_Tree)

# RepRap and its children... Makerbot



Again, the evolution of an open source project that's too big to fit into one slide...

Source: <http://en.wikipedia.org/wiki/Makerbot>

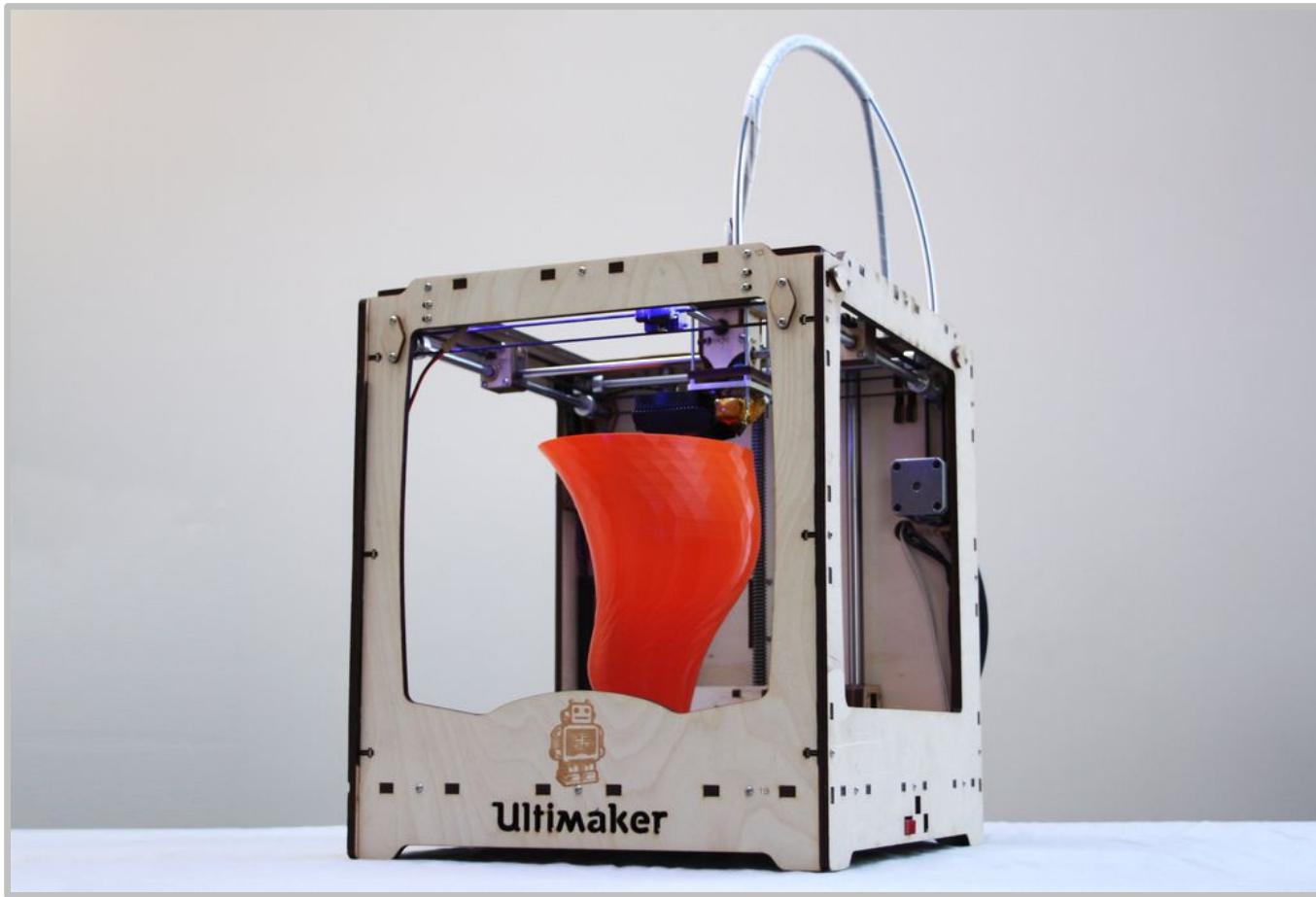
# RepRap and its children... Makerbot



Again, the evolution of an open source project that's too big to fit into one slide...

Source: <http://store.makerbot.com/replicator-404.html>

# RepRap and its children... Ultimaker

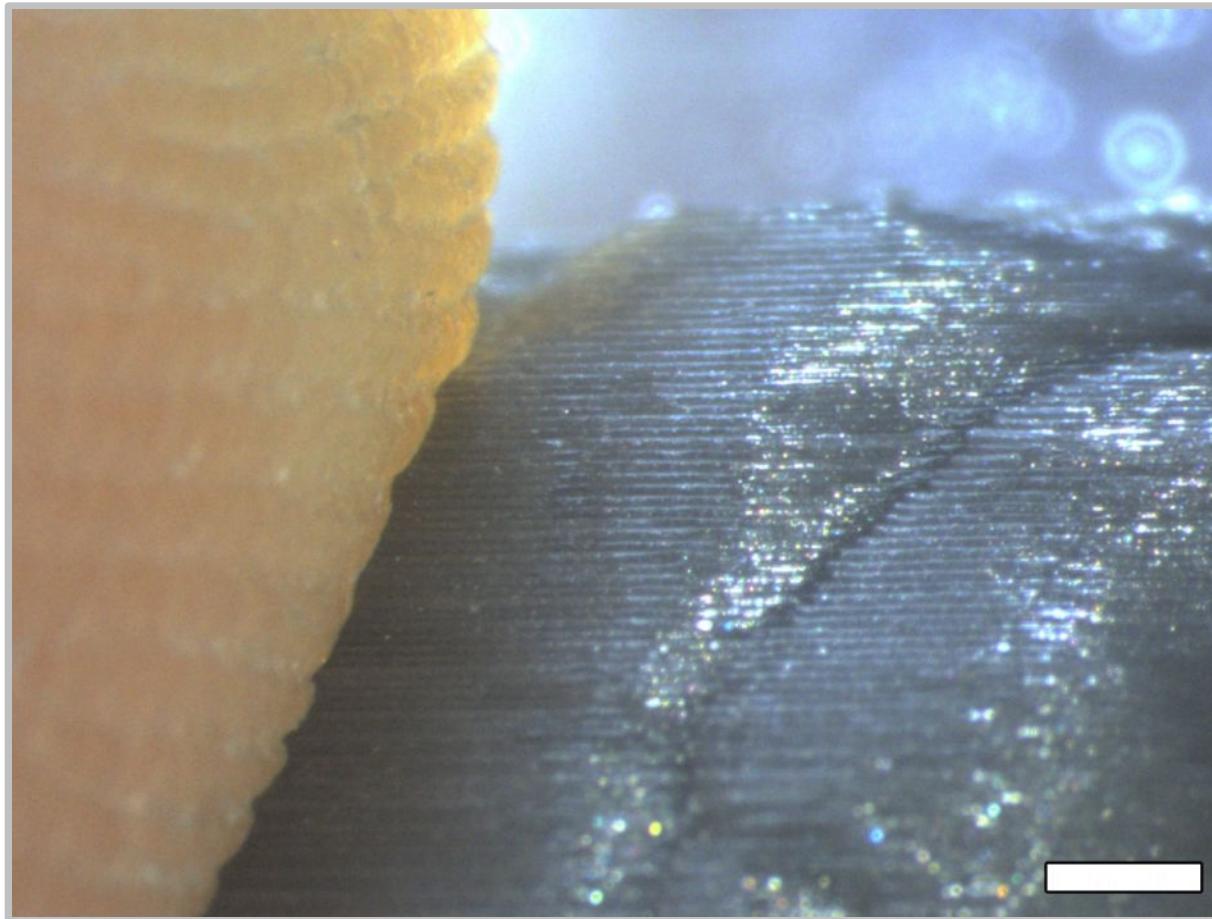


---

Again, the evolution of an open source project that's too big to fit into one slide...

Source: <http://reprap.org/wiki/Ultimaker>  
<http://blog.ultimaker.com/>

# RepRap and its children... Ultimaker



---

The average layer height in that pic is around 0.074 mm (that is 74 microns).

Source: <http://www.hive76.org/insane-3d-printing-resolution-ultimaker-under-the-micro>

# A portable 3D printer...



PopFab: at its heart is a computer-controlled motion platform and a means of attaching various toolheads.

Source: [http://www.core77.com/blog/digital\\_fabrication/a\\_suitcase-sized\\_3-in-1\\_cnc\\_multi-tool\\_23007.asp](http://www.core77.com/blog/digital_fabrication/a_suitcase-sized_3-in-1_cnc_multi-tool_23007.asp)  
<http://vimeo.com/45911972>



Aalto University  
Media Factory

02.

## 3D printing: examples what people are doing with it

# Printable VELCRO

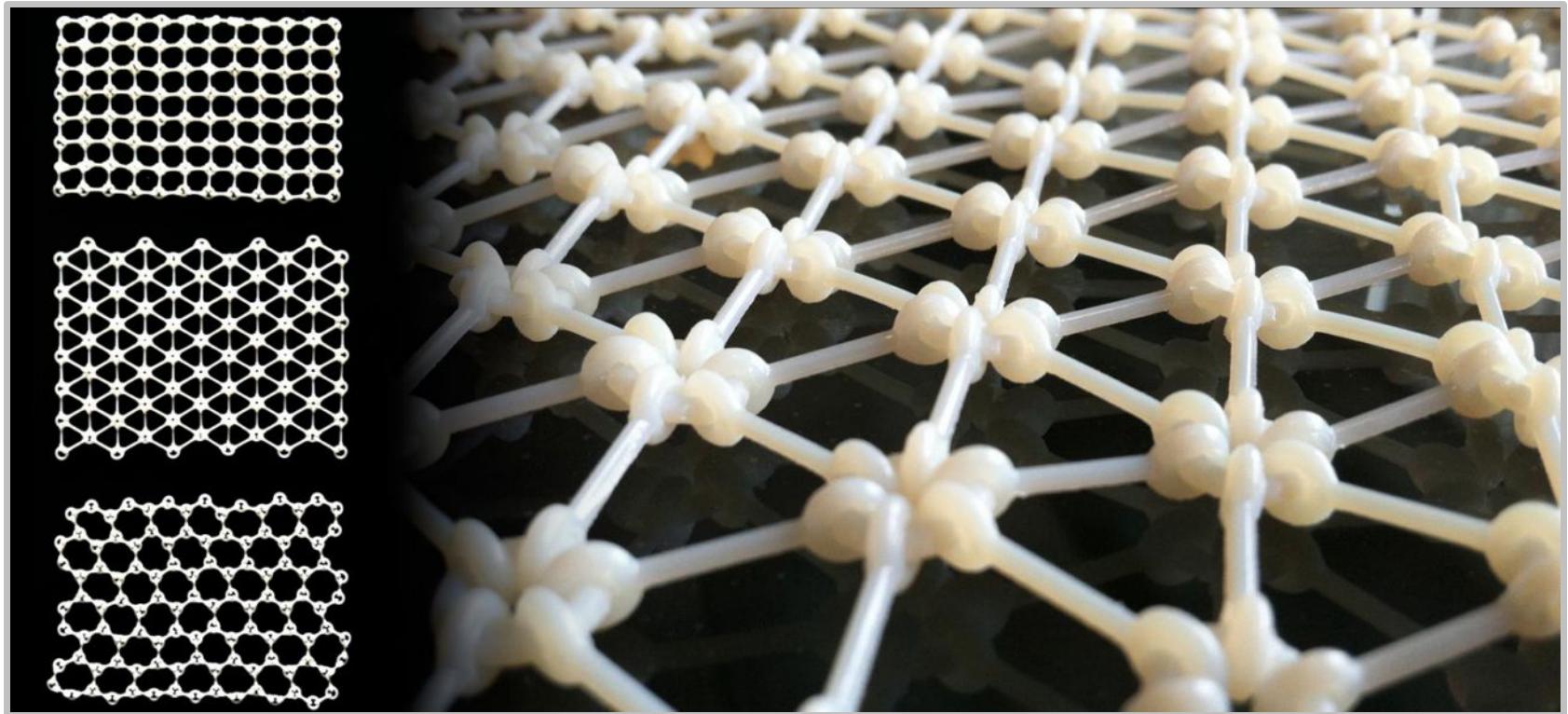


---

The velcro is printed with 0.3mm ABS with a  
MK6 extruder on a Makerbot.

Source: <http://www.thingiverse.com/thing:12798>

# 3D Printing Flexible Grids

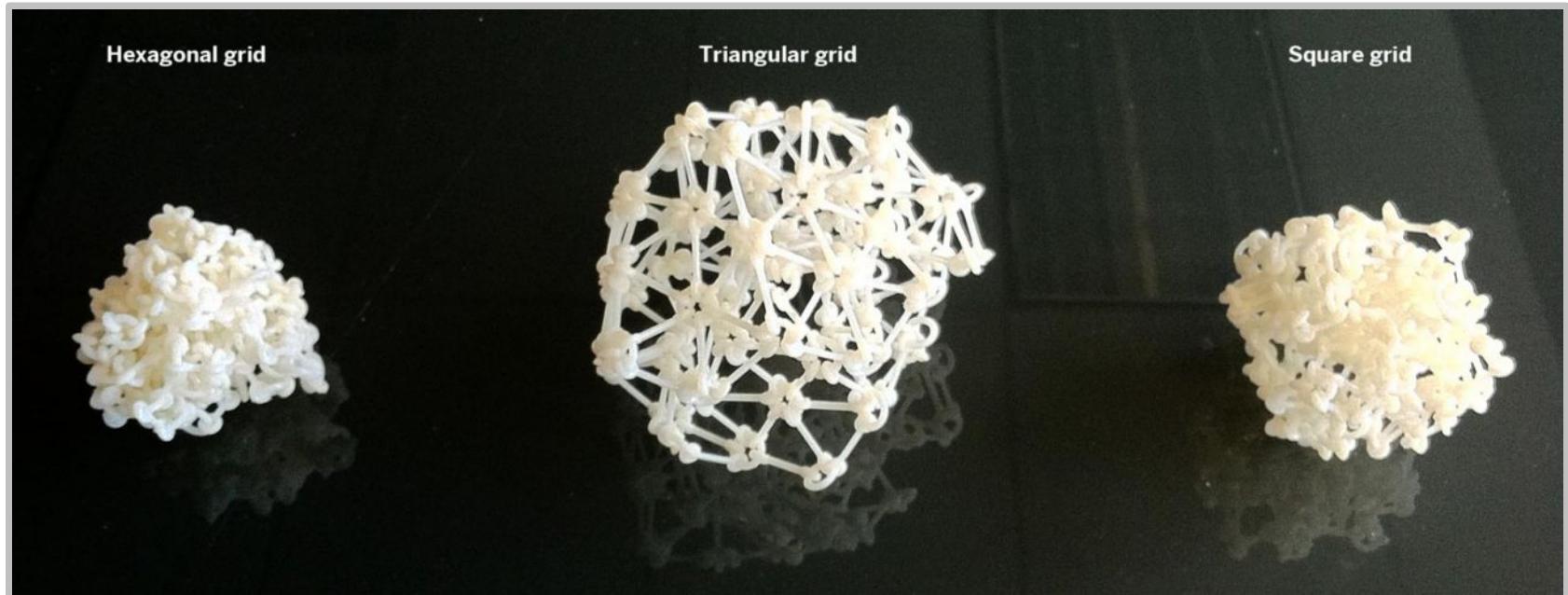


---

Done with a Grasshopper definition that used the grid components to create a set of flexible triangular, square, and hexagonal grids.

Source: <http://lmnts.lmnarchitects.com/fabrication/printed-flexgrids/>

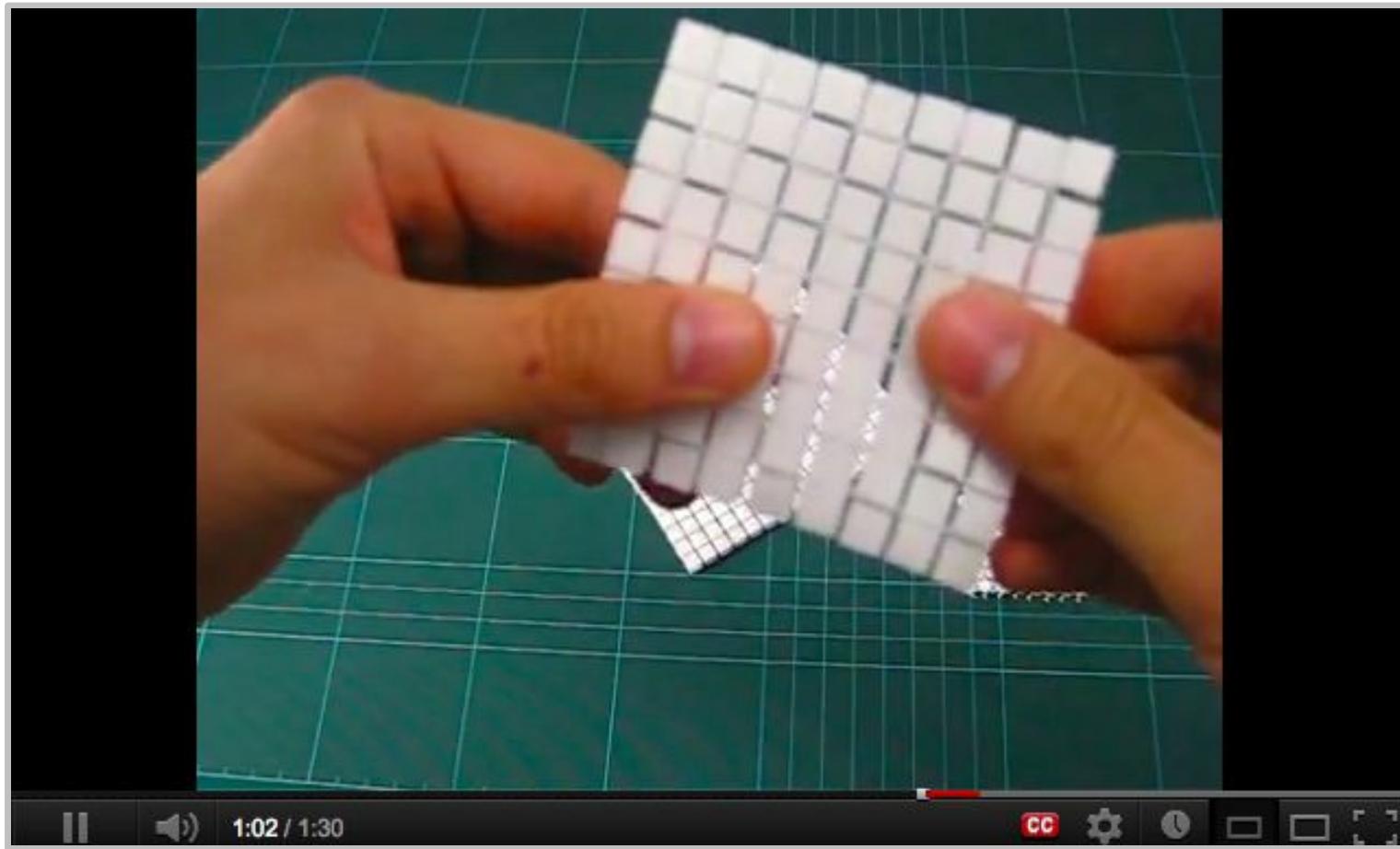
# 3D Printing Flexible Grids



Done with a Grasshopper definition that used the grid components to create a set of flexible triangular, square, and hexagonal grids.

Source: <http://lmnts.lmnarchitects.com/fabrication/printed-flexgrids/>

# Digi-Fabrics



A test done by Shapeways with their White Strong & Flexible material.

Source: <http://youtu.be/JSCDw6mThk4>

<http://www.shapeways.com/blog/archives/525-White-Strong-and-Suuuper-Flexible..html>

# 3D printed bikini



---

The N12 bikini is the world's first ready-to-wear, completely 3D-printed cloth. All of the pieces are snap together without any sewing.

Source: <http://www.continuumfashion.com/N12.html>

# 3D printed fashion design



---

Dutch designer Iris Van Herpen uses 3-D printers to create designer fashion for Björk and Lady Gaga.

Source: <http://www.wired.com/design/2012/04/10-things-3d-printers-can-do-now?pid=167>

# 3D printed fashion design



---

A collection of 3D printed hats and accessories were shown on the runway as part of the Materialise World Conference in Leuven, Belgium.

Source: <http://blog.ponoko.com/2012/04/24/a-fashion-show-of-3d-printed-hats/>  
<http://i.materialise.com/challenge/the-hats-off-to-3d-printing-challenge/>

# 3D printed shoes



Melissas' shoes are among the most amazing examples of what 3D printing can do for style and design. Designer Andreia Chaves created the Invisible Shoes

Source: <http://blog.sculpteo.com/2012/03/29/3d-printing-for-green-fashion-melissas-footwear-experiments/>

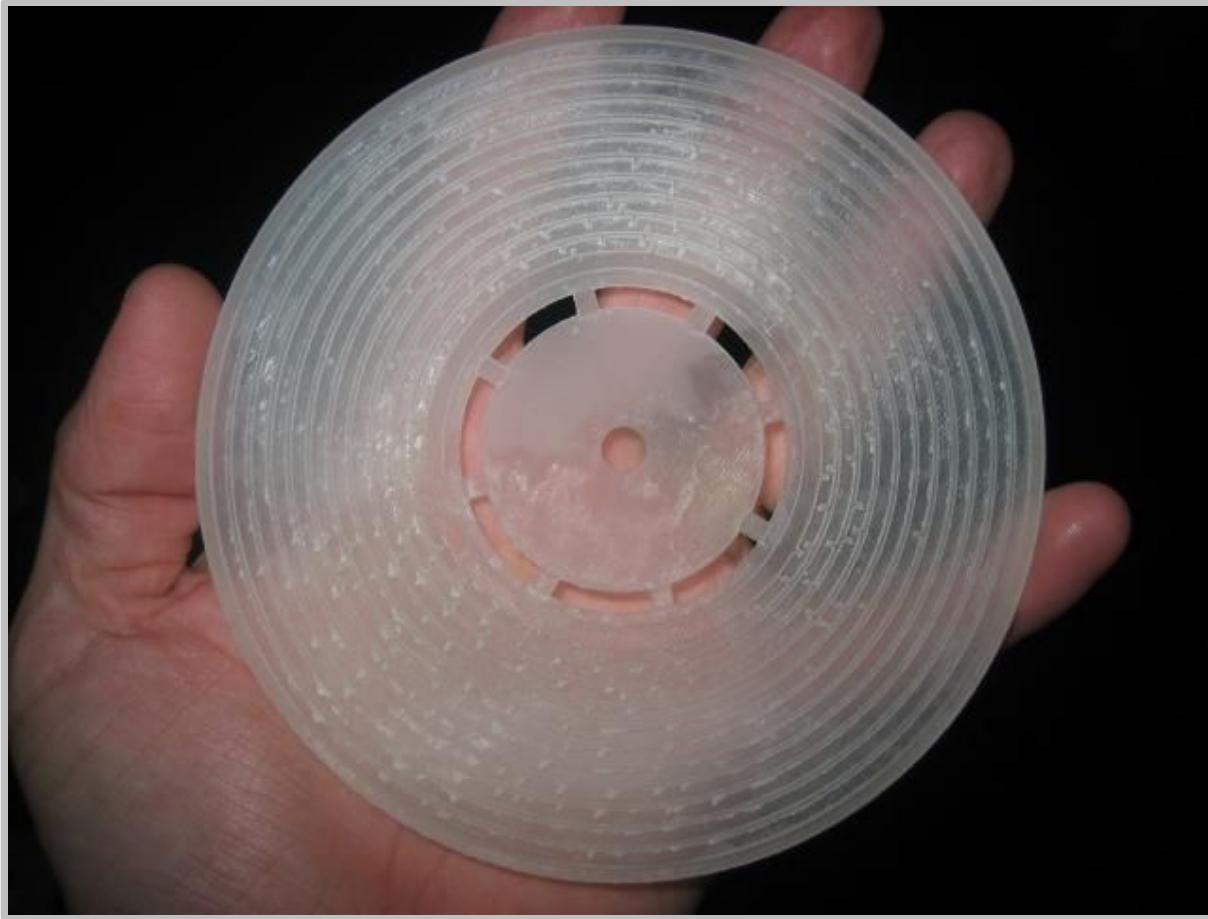
# 3D printed characters



Yoni Binstock is using front and side portrait photos together with 123D Catch to reconstruct a facial model and texture this on to a cake topper design.

Source: <http://www.shapeways.com/blog/archives/1332-Lifes-Memorable-Moments-Captured-In-3D.html>

# 3D printing media...



---

A 3D printed record for the Fisher-Price record player playing 'Still Alive'. The tune and model were all generated in Processing. Sold on Shapeways.

Source: <http://www.shapeways.com/blog/archives/1179-Video-of-3D-Printed-Record-Playing-Still-Alive-from-Portal.html>

# 3D printing media...



A 3D printed record for the Fisher-Price record player playing 'Still Alive'. The tune and model were all generated in Processing. Sold on Shapeways.

Source: <http://youtu.be/EIAJJnSvQtk>

# 3D printing media...



The first 3D printed prototype of the programmable kalimba sequencer.  
Pegs can be set to produce different 16-step sequences of 5 tones.

Source: <http://youtu.be/ERiw664xMKE>

# 3D printing media...



3D printing of film props has long been common in big budget movies, but now its increased affordability is aiding its introduction to smaller budget productions.

Source: <http://youtu.be/aMfSGt6rHos>

<http://blog.ponoko.com/2011/12/11/3d-prints-in-stop-motion-animation/>

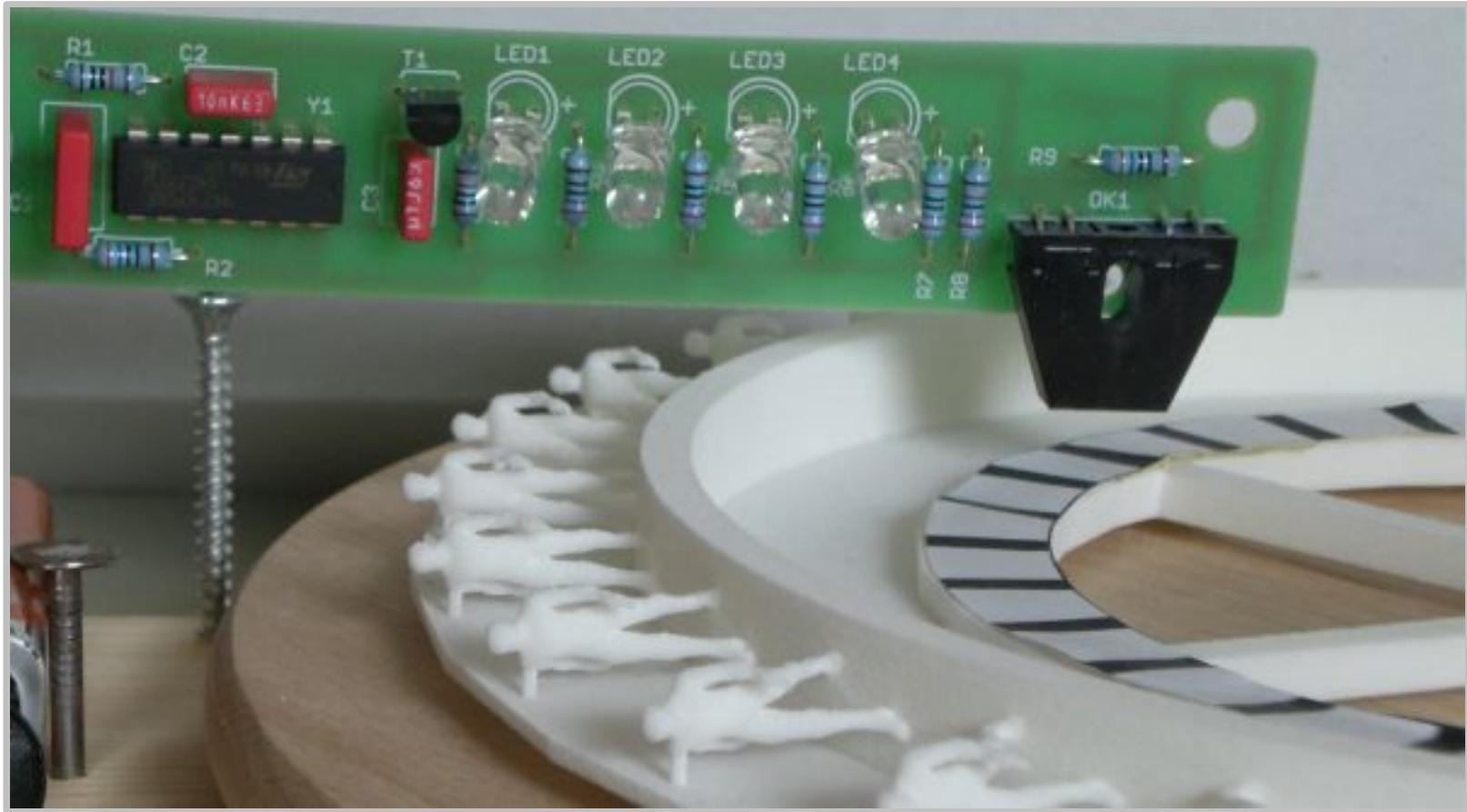
# 3D printing media...



With the help of technologies from Objet Geometries, the creative team behind the feature film, Coraline, broke new ground in stop-motion animation.

Source: [http://youtu.be/\\_2F0PA7qUQE](http://youtu.be/_2F0PA7qUQE)

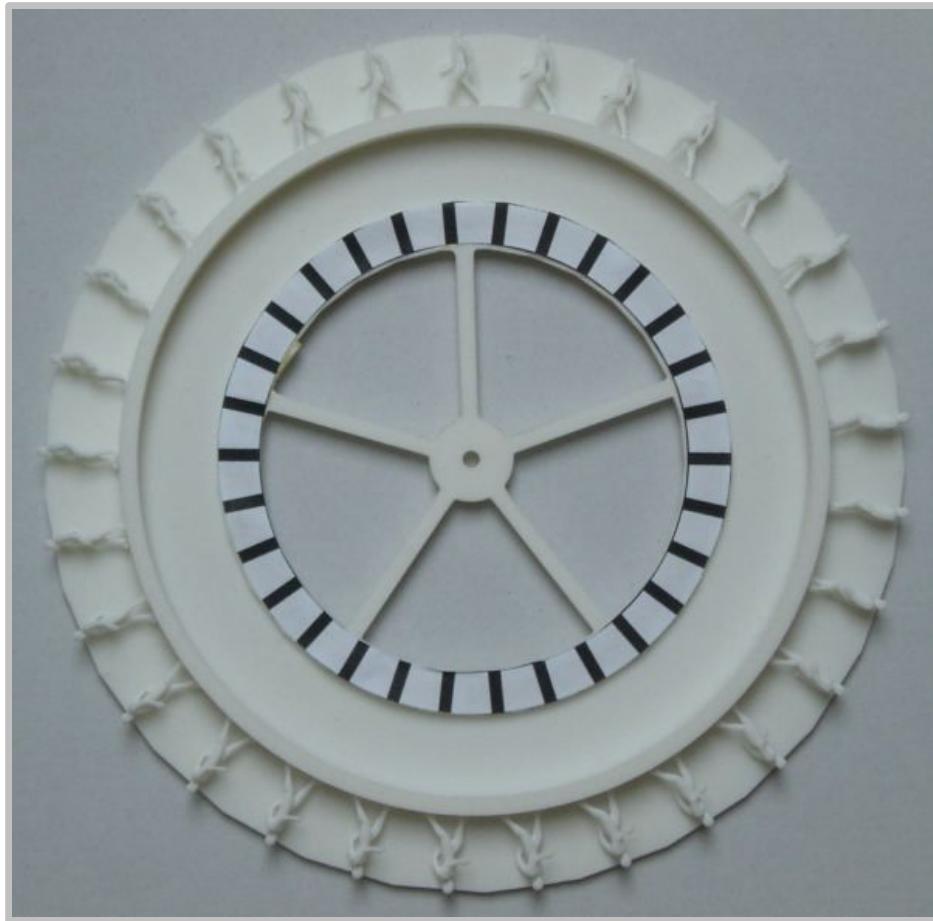
# 3D printing media...



3Drehkino took an animation in Blender, 3D printed it with Shapeways, hacked some electronics and created his own zeotrope under a CC license.

Source: [http://drehkino.de/3Drehkino\\_en.php](http://drehkino.de/3Drehkino_en.php)

# 3D printing media...



---

3Drehkino took an animation in Blender, 3D printed it with Shapeways, hacked some electronics and created his own zeotrope under a CC license.

Source: [http://drehkino.de/3Drehkino\\_en.php](http://drehkino.de/3Drehkino_en.php)

# 3D printing media...



3Drehkino took an animation in Blender, 3D printed it with Shapeways, hacked some electronics and created his own zeotrope under a CC license.

Source: [http://youtu.be/LVa\\_WwBFtA4](http://youtu.be/LVa_WwBFtA4)

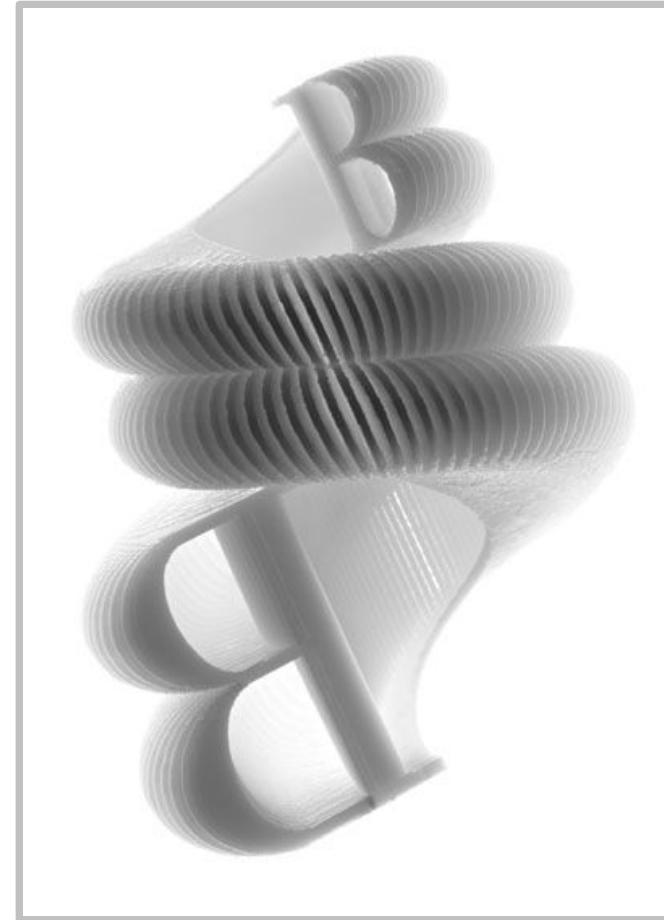
# 3D printing in media: Print magazine cover



Print magazine August 2008 cover design generated with Processing and 3D printed.

Source: [http://postspectacular.com/process/20080702\\_printmagcover](http://postspectacular.com/process/20080702_printmagcover)

# 3D printing in media: Arkitypo

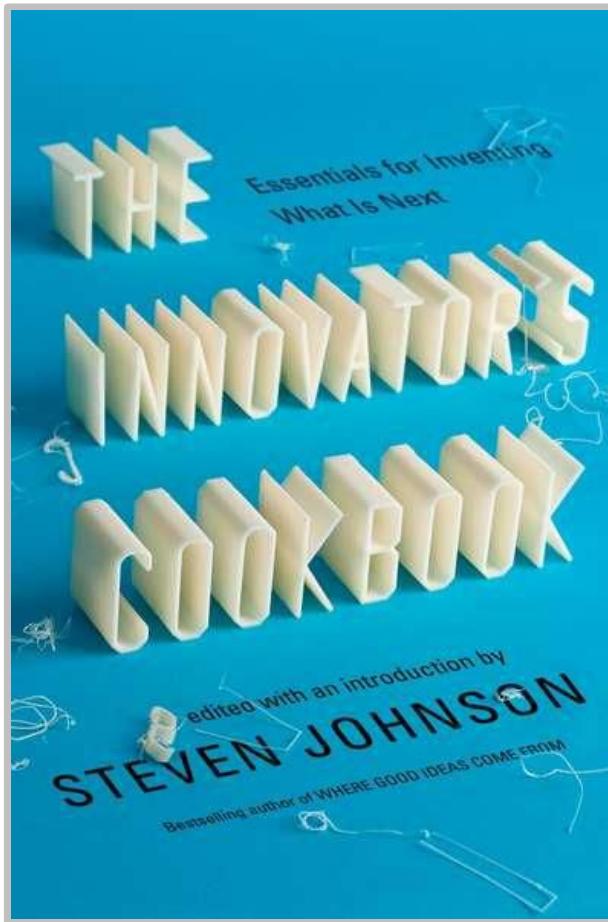


---

The idea was to 3D-print an entire alphabet derived from the historical story of how a typeface beginning with the same letter came to be.

Source: <http://johnsonbanks.co.uk/thoughtfortheweek/index.php?thoughtid=711>

# 3D printing in media



---

Printing the cover of the book *The Innovator's Cookbook* by Steven Johnson with a Makerbot.

Source: <http://www.casualoptimist.com/2011/10/18/the-innovators-cookbook/>

# 3D printing in media



Printing the cover of the book *The Innovator's Cookbook*  
by Steven Johnson with a Makerbot.

Source: <http://youtu.be/S2EqxdvOKVc>  
<http://www.casualoptimist.com/2011/10/18/the-innovators-cookbook/>

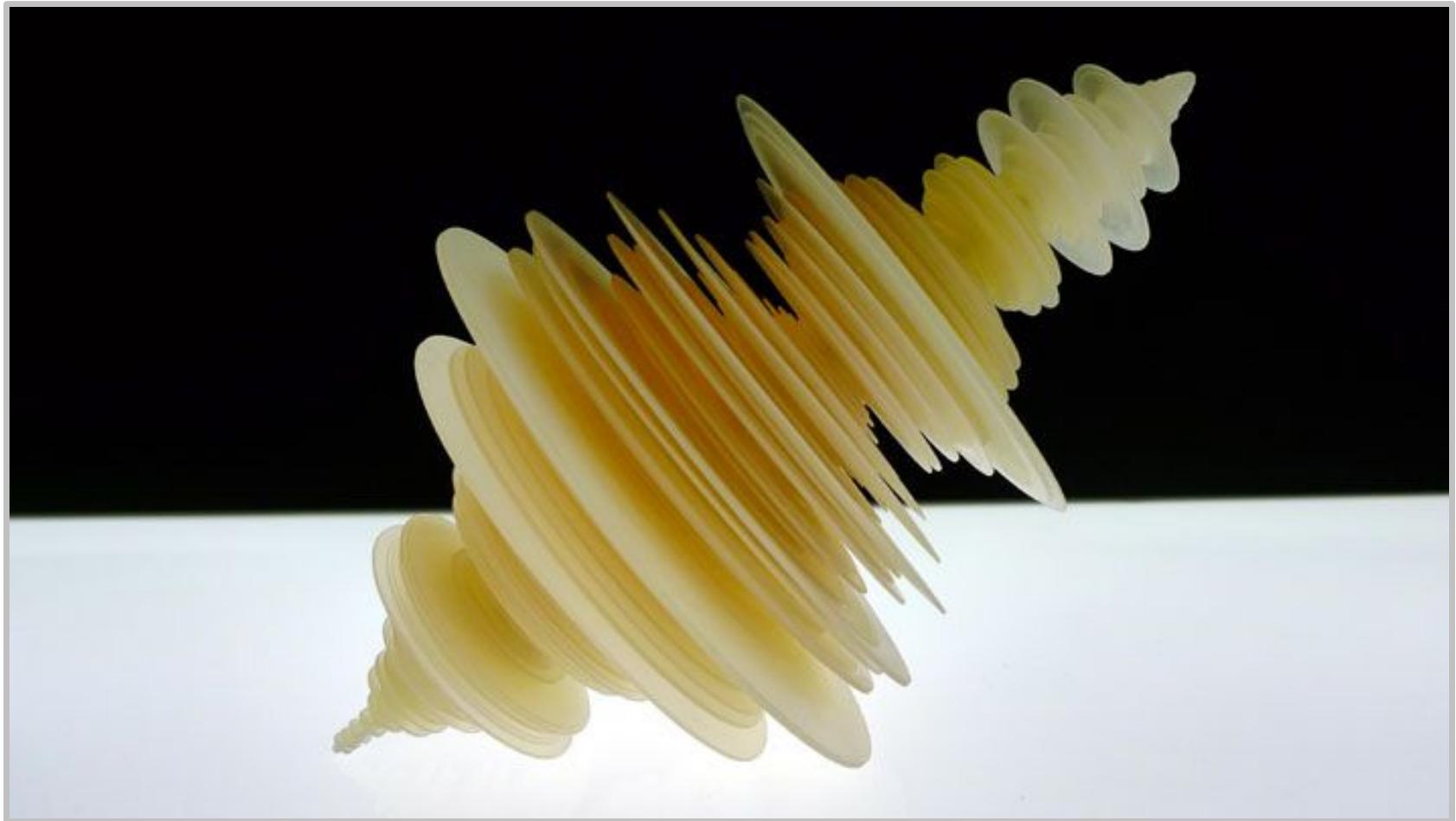
# Successful transplant of a 3D printed jaw



A 3D printer-created lower jaw has been fitted to an 83-year-old woman's face in what doctors say is the first operation of its kind.

Source: <http://www.bbc.co.uk/news/technology-16907104>

# 3D printing data: Luke Jerram



To create the sculpture a seismogram of the earthquake, was rotated and then printed in 3 dimensions using rapid prototyping technology.

Source: [http://www.lukejerram.com/projects/t%C5%8Dhoku\\_earthquake](http://www.lukejerram.com/projects/t%C5%8Dhoku_earthquake)

# 3D printing data: sound

The screenshot shows the homepage of the Shapeways 'the vibe' service. At the top, there's a logo consisting of the Shapeways and SoundCloud logos plus a plus sign, followed by an equals sign and the 'the vibe' logo. Below this, the main title 'Sound You Can Touch' is displayed in large, bold, dark letters. A subtitle below it reads '3D print a custom iPhone case with your favorite sound from SoundCloud'. A large orange 'Get Started!' button is centered. Below the button, a link says 'Never heard of SoundCloud? [Find out more.](#)'. The bottom section, titled 'Here's How It Works...', shows three steps: connecting to SoundCloud (illustrated with a plug icon and a SoundCloud waveform), choosing a sound (illustrated with a screenshot of the Shapeways website showing a sound visualization and a price of \$19.95), and getting the custom iPhone case (illustrated with a hand holding a phone with a 3D-printed soundwave pattern on its back).

shapeways + SOUNDCLiND = the vibe

# Sound You Can Touch

3D print a custom iPhone case with your favorite sound from SoundCloud

Get Started!

Never heard of SoundCloud? [Find out more.](#)

Here's How It Works...

Connect to SoundCloud.

Choose your favorite sound.

Get your custom iPhone case!

“Welcome to the era of mass customization in which anyone can build a unique iPhone case for \$25.”

Source: <http://www.shapeways.com/creator/thevibe>

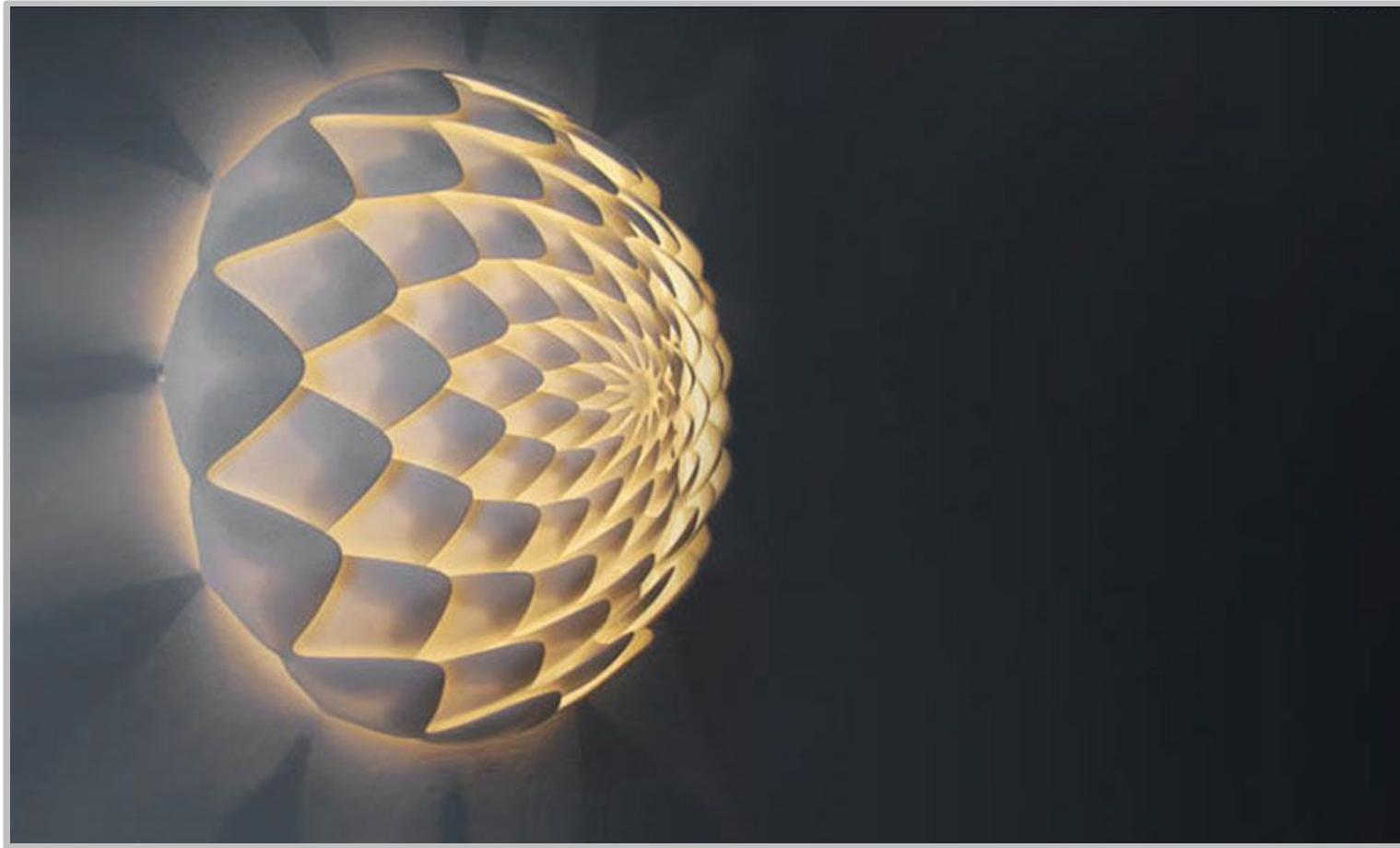
# 3D printing data: sound



“Welcome to the era of mass customization in which anyone can build a unique iPhone case for \$25.”

Source: <http://www.protoparadigm.com/2011/11/filament-tolerances-and-print-quality/>

# 3D printed lamps



---

Freedom Of Creation is an edition of exclusive design objects,  
furnishing complements, lighting and accessories.

Source: <http://www.freedomofcreation.com/>

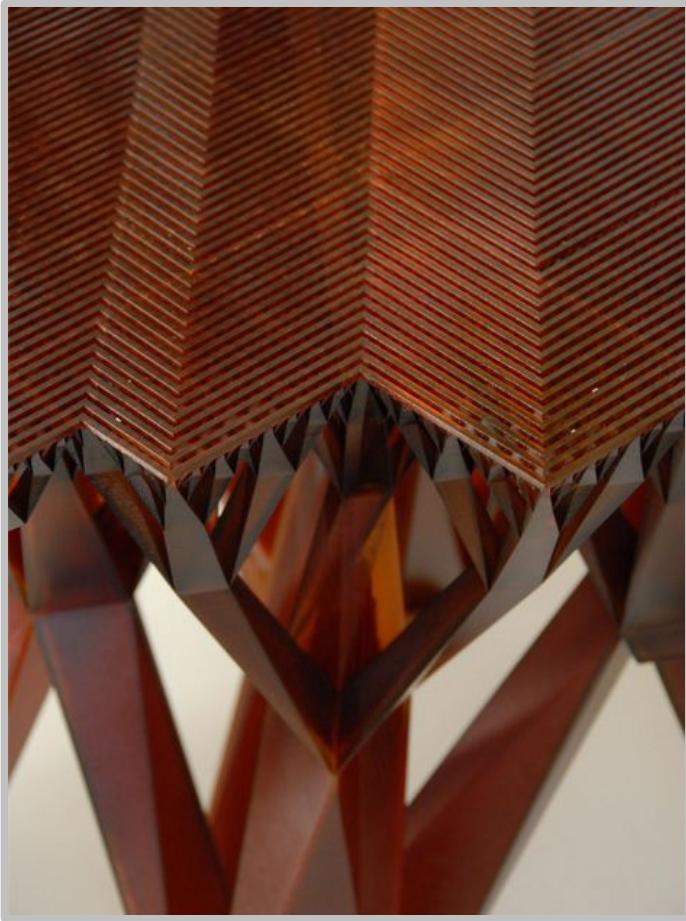
# 3D fractal furniture design



Fractal Table is a generative design table produced by Materialise as a single piece SLA in epoxy resin. Its dimensions in cm are: L98 x W61 x H42.

Source: <http://www.platform-net.com/>

# 3D fractal furniture design

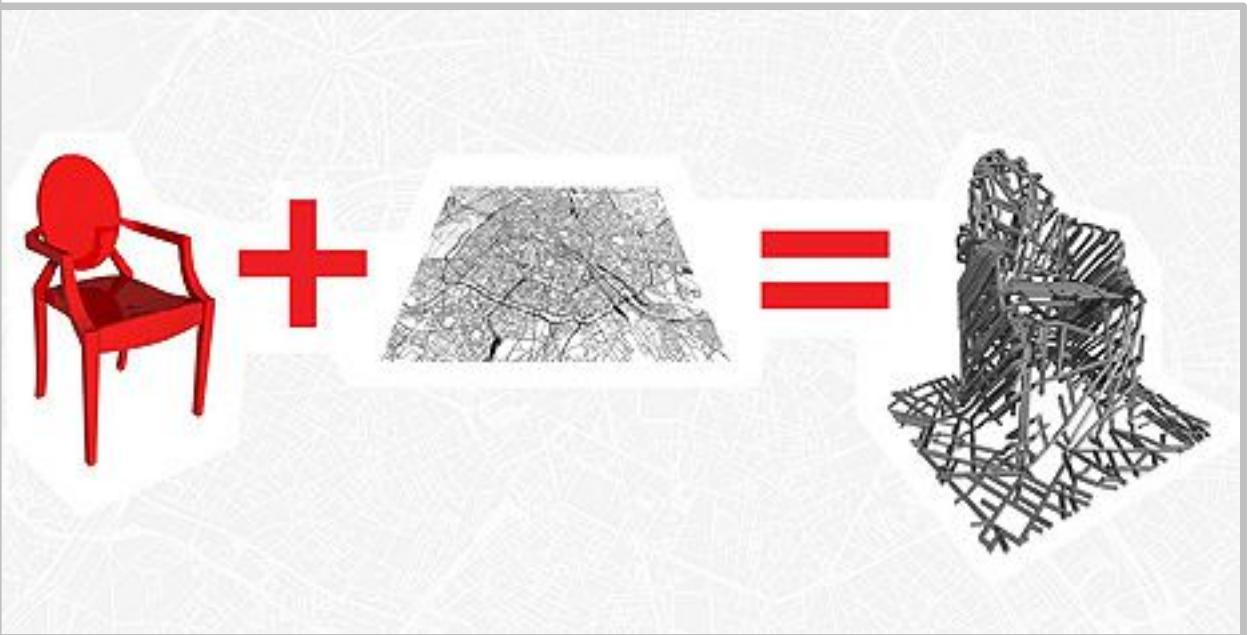


---

Fractal Table is a generative design table produced by Materialise as a single piece SLA in epoxy resin. Its dimensions in cm are: L98 x W61 x H42.

Source: <http://www.platform-net.com/>

# 3D printed furniture design



---

The Throne of Paris (John Briscella)

Source: <http://i.materialise.com/blog/entry/5-amazing-full-sized-furniture-pieces-made-with-3d-printing>

# 3D printed guitar



Each guitar is fully customizable, as the designers remove or insert various segments from the 3D model before each printing, with selectable colour.

Source: <http://www.designboom.com/weblog/cat/16/view/20135/skeletal-3d-printed-guitar.html>

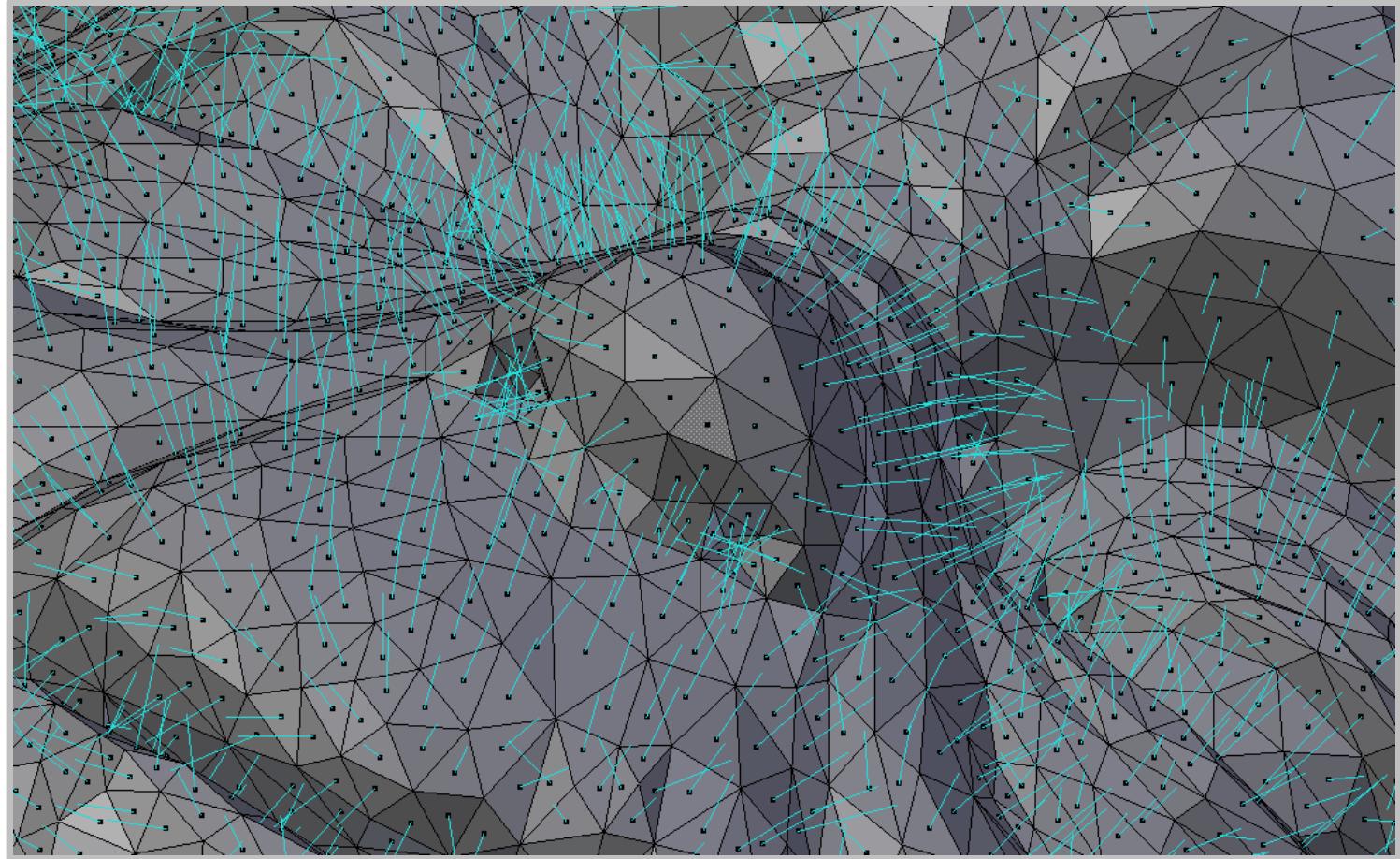


Aalto University  
Media Factory

03.

# 3D printing: design techniques things to consider...

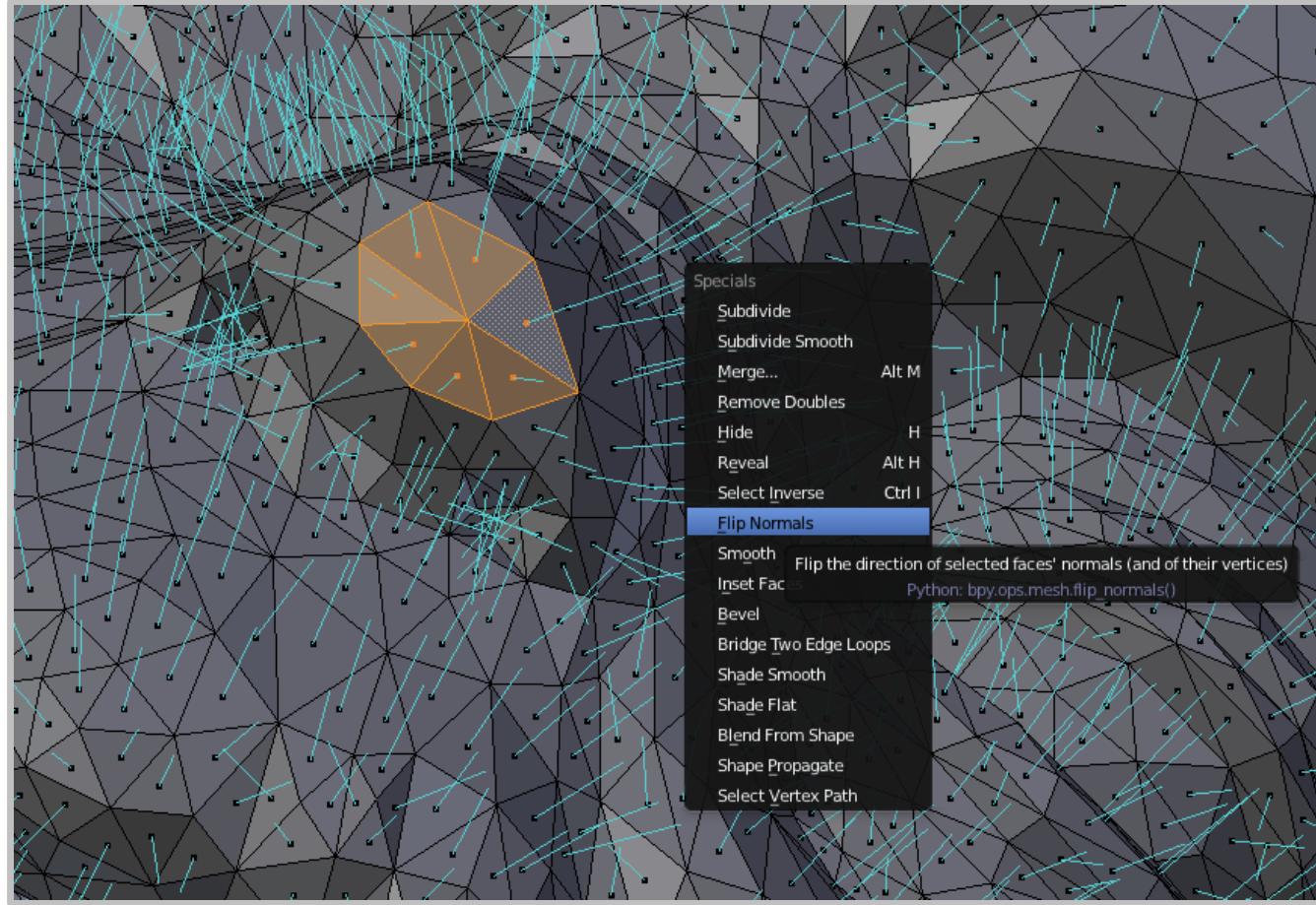
# 01: check the normals



---

They should point outwards! The faces of a mesh are only 1-side.

# 01: check the normals



---

Edit mode > W > Flip normals

# 02: check your technology

## Watch out with very thin connections

The droplet below necks down to a very thin cross-section. The droplet on the end is too large then goes to a small cross-section. This will crack or tear.

"Water Crown Chopsticks stand", by [wuct88](#)



Check your specific material and technology,  
Shapeways is a good resource.

Source: [http://www.shapeways.com/tutorials/design\\_rules\\_for\\_glass\\_3d\\_printing](http://www.shapeways.com/tutorials/design_rules_for_glass_3d_printing)

## 03: Yes to moving parts and undercuts



But not with FDM!!!

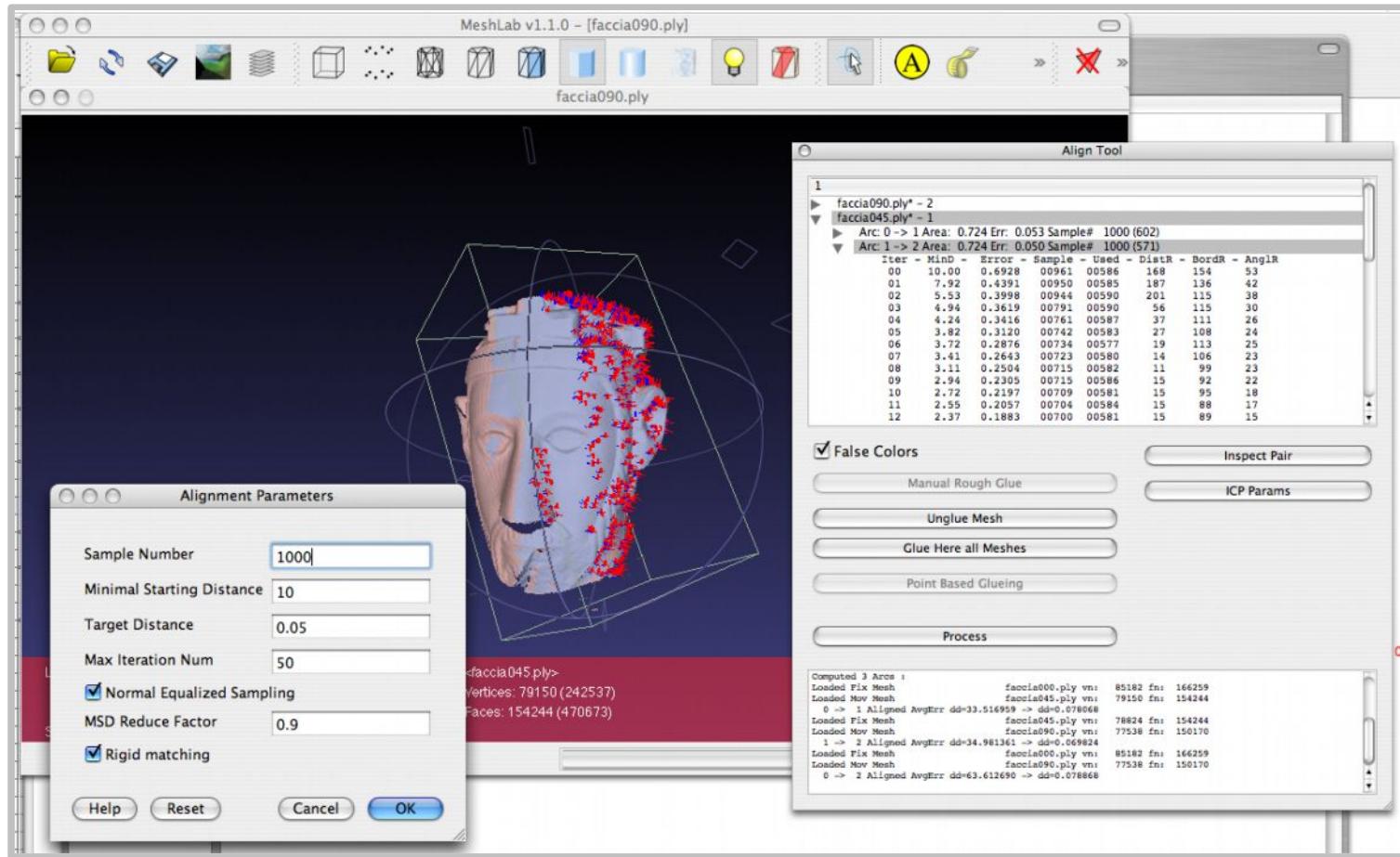
# 03: FDM: use support material



PVA is the best option, it is water soluble.

Source: <http://youtu.be/FqhBmNyvNhQ>  
<http://store.makerbot.com/makerbot-pva-1kg-spool.html>

# 04: Clean it with Netfabb / Meshlab



And you may need to import it into Blender again.

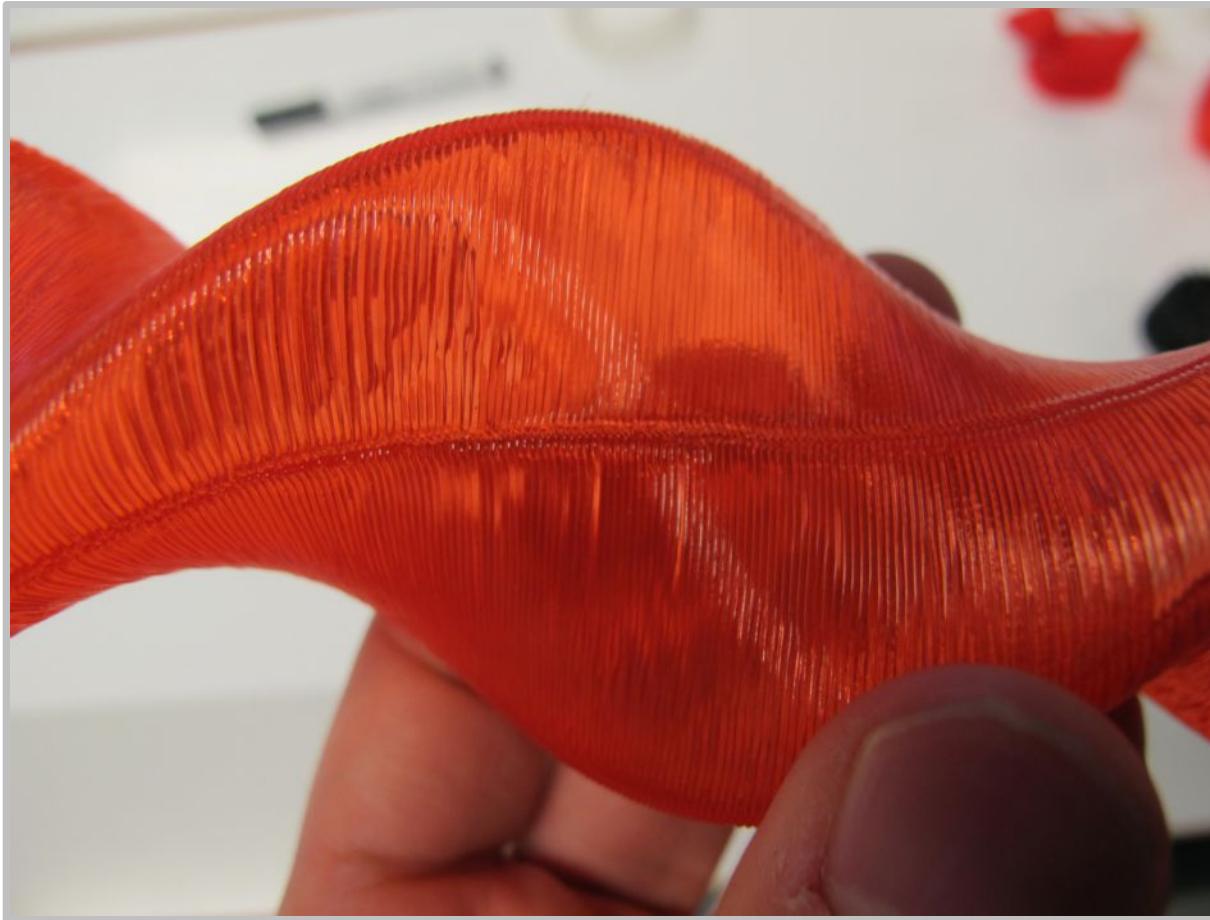
# 3D printing: what could go wrong?



---

Too fast: we cannot achieve the full cylinder.  
We had to slow the speed down and rise a bit the temperature.

# 3D printing: what could go wrong?



---

Too fast: we cannot achieve the full cylinder.  
We had to slow the speed down and rise a bit the temperature.

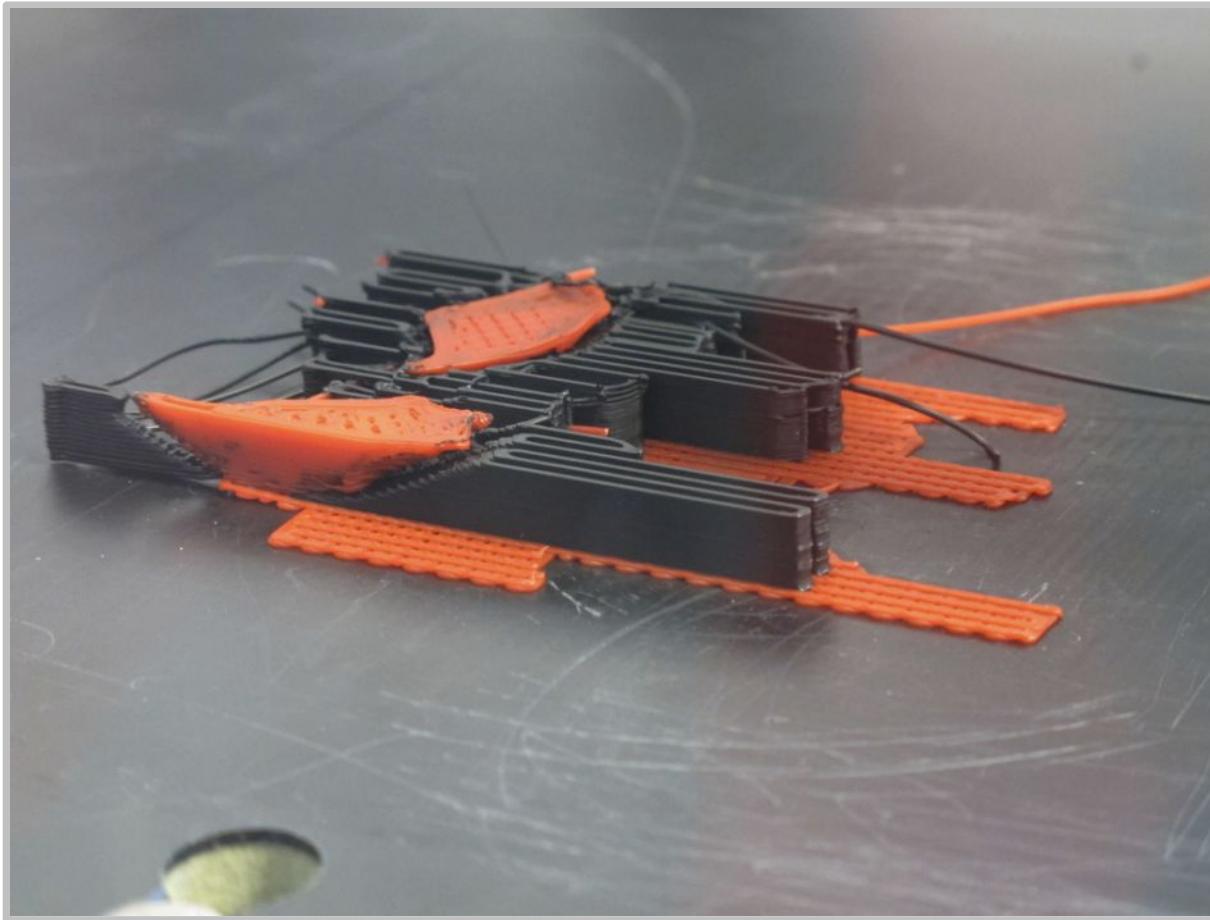
# 3D printing: what could go wrong?



---

Too fast: the material does not have the time to solidify.  
Also: too thin, and the roof collapses. On the right: slower and bigger detail.

# Think about the speed



---

Each different material melt at a different temperature,  
mixing them means slowing down the process.

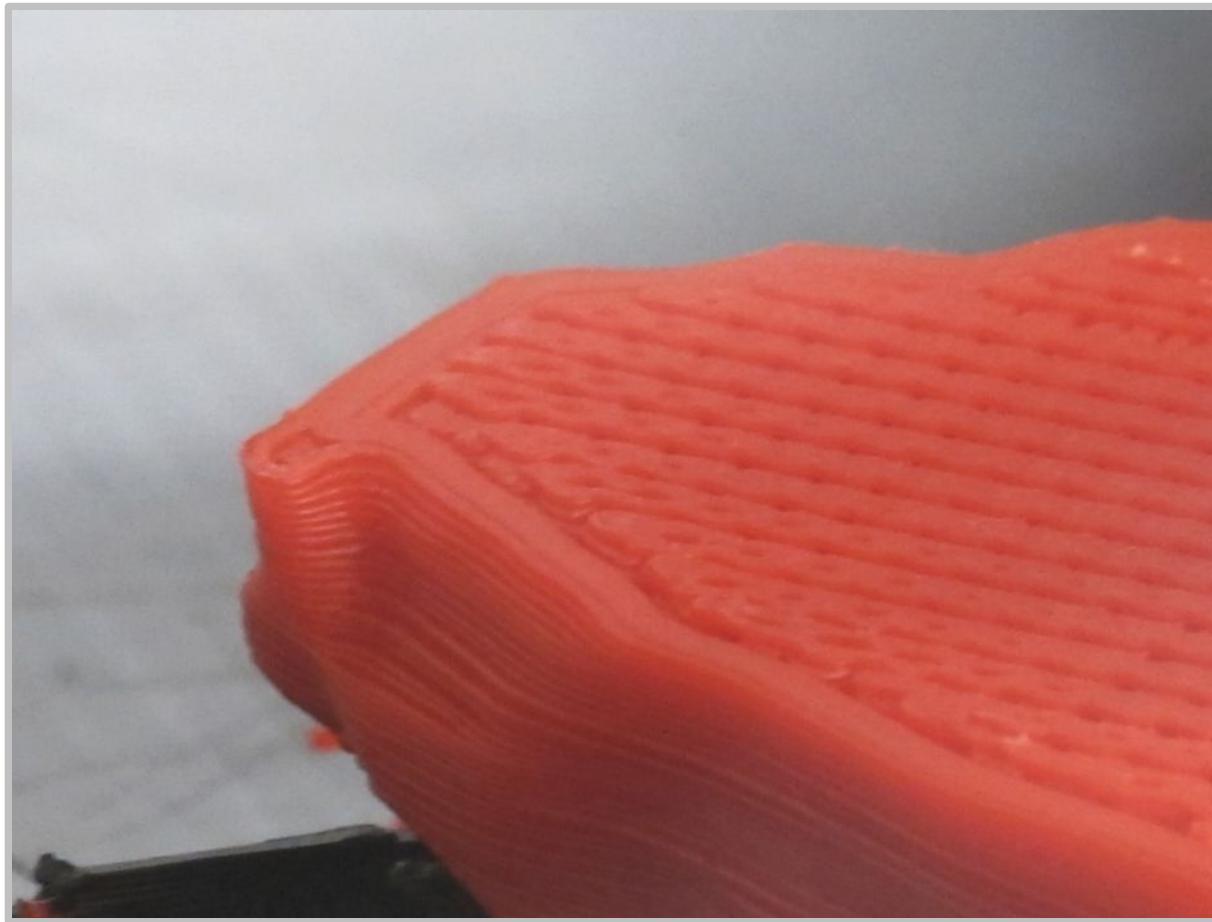
# Resolution



---

0.5 or 0.25 or 0.125 mm? Higher resolution =  
more time for printing.

# Skins and filling



---

You can add extra skins and reduce the density of the filling, if you just need a shell.

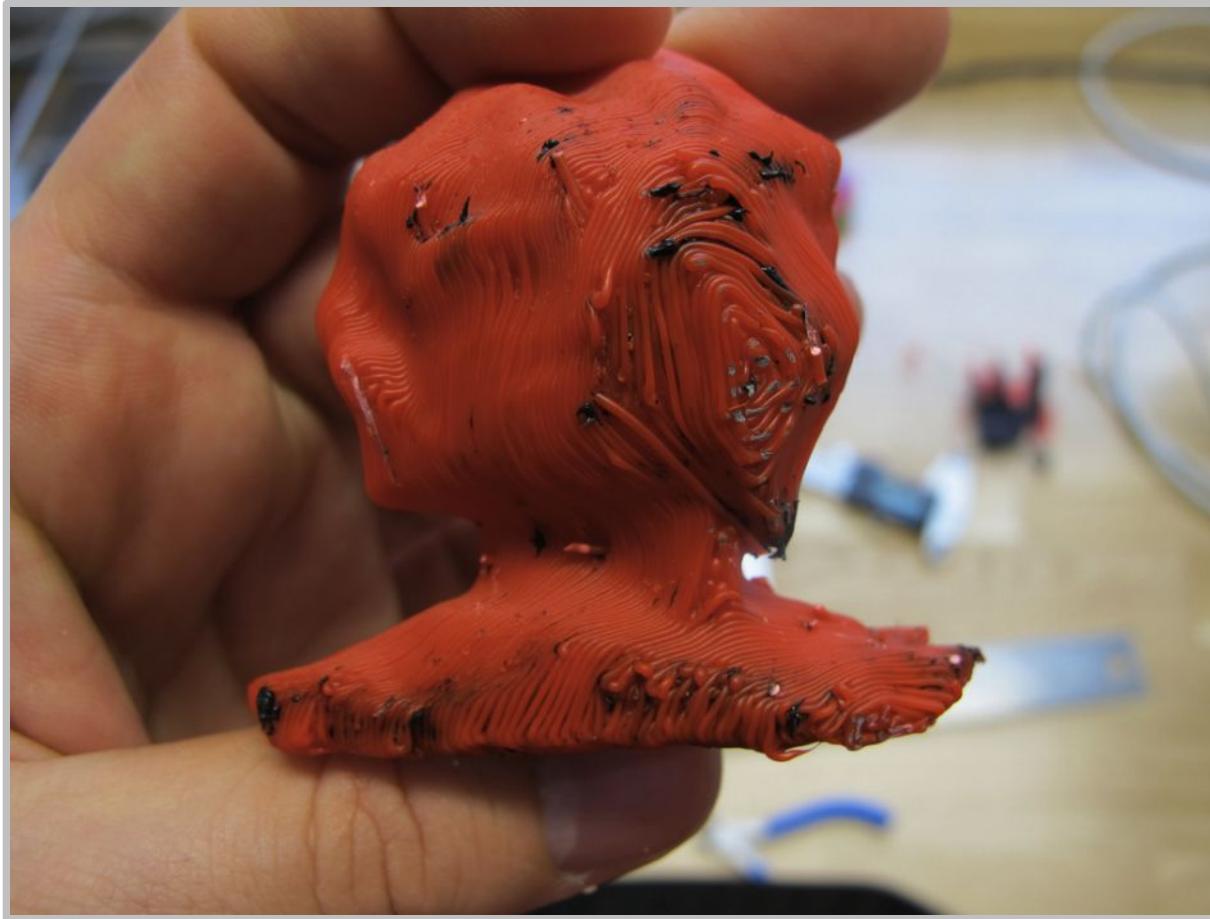
# 123D Catch: result



---

See the orientation of the layers?

# 123D Catch: result



---

Support material (PLA) and object material  
(ABS) mixed a bit.

# A”

Aalto University  
Media Factory

# Thank you!!

Massimo Menichinelli  
Aalto Media Factory  
[massimo.menichinelli@aalto.fi](mailto:massimo.menichinelli@aalto.fi)  
@openp2pdesign  
<http://www.slideshare.net/openp2pdesign>



21.05.2012  
Aalto Media Factory  
Helsinki