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# Digital\_Fabrication\_Studio.06

## CNC milling - materials, finishes, process

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# Today:

- \* CNC Milling
- \* CNC, but not only Milling
- \* Examples
- \* Design techniques

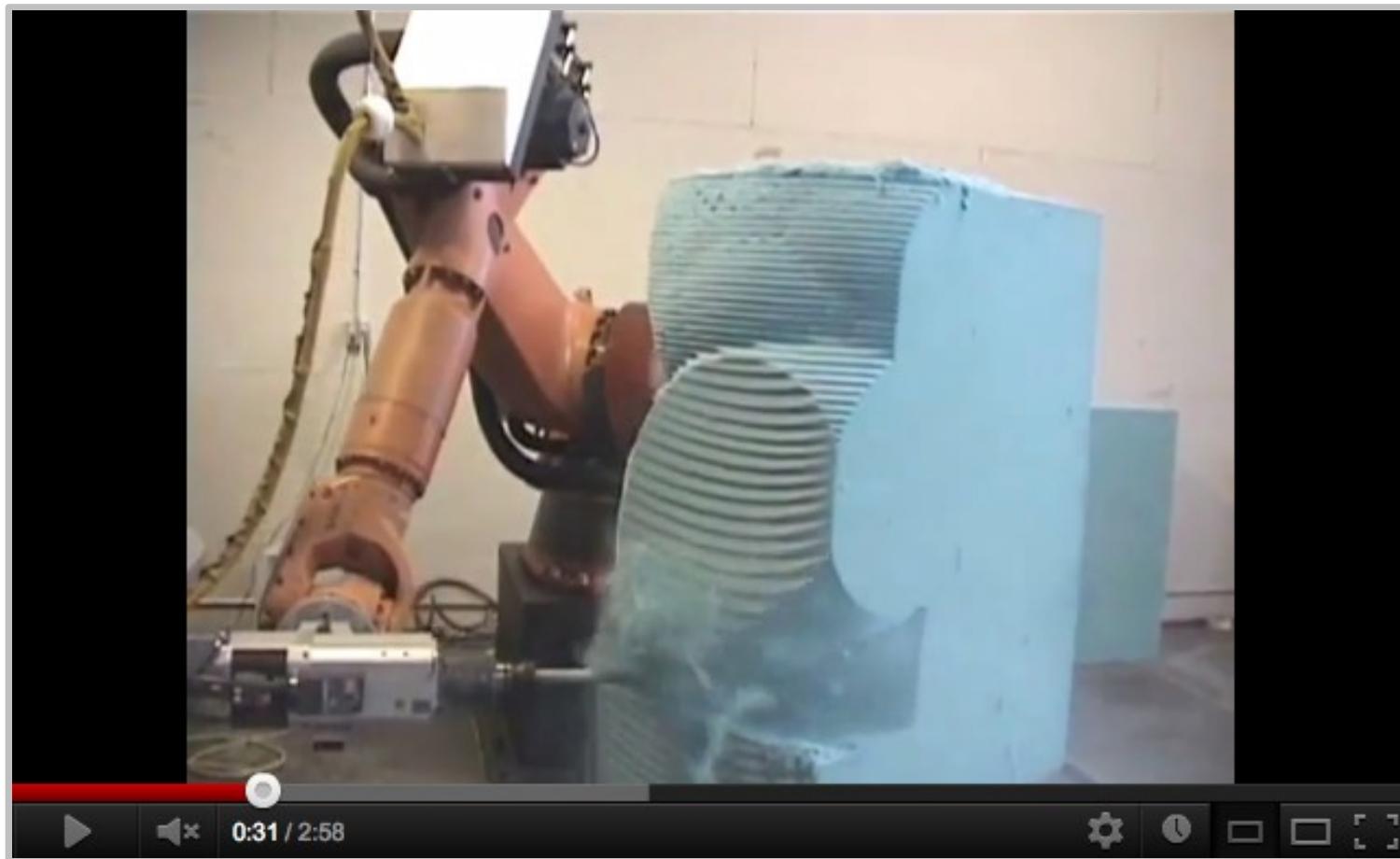


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01.

# CNC Milling: computer controlled sculptures

# CNC milling



Sculpting (subtracting) from a block of  
(almost) any material.

Source: <http://youtu.be/j4akxGjTbOs>

# CNC routing



Routing = different technology, different speed and resistance (more suitable for wood than metal).

Source: <http://youtu.be/C5t0YWfhuyM?t=50s>

# CNC milling: 2D, 2.5D or 3D ?



2D or 2-axis (only X and Y), 2.5D or 2-axis (X,Y, and up/down position), 3D or 3-axis (X,Y,Z).

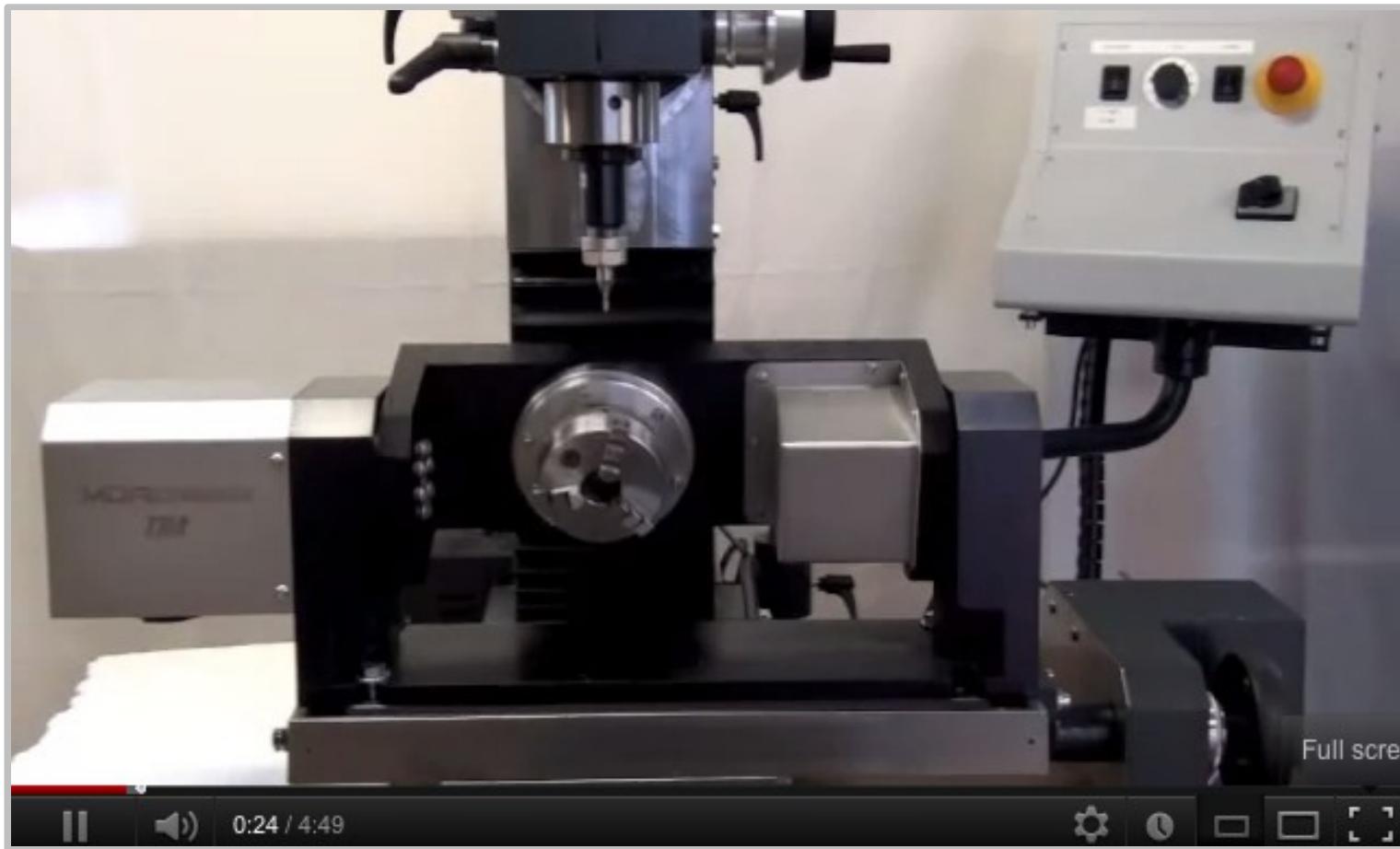
# CNC milling: 4-axis



An example: Roland MDX-540 (but there's also a desktop version, the MDX-40A).

Source: [http://youtu.be/ZuXF\\_Y97j2M](http://youtu.be/ZuXF_Y97j2M)  
<http://www.rolanddga.com/products/milling/mdx540/>

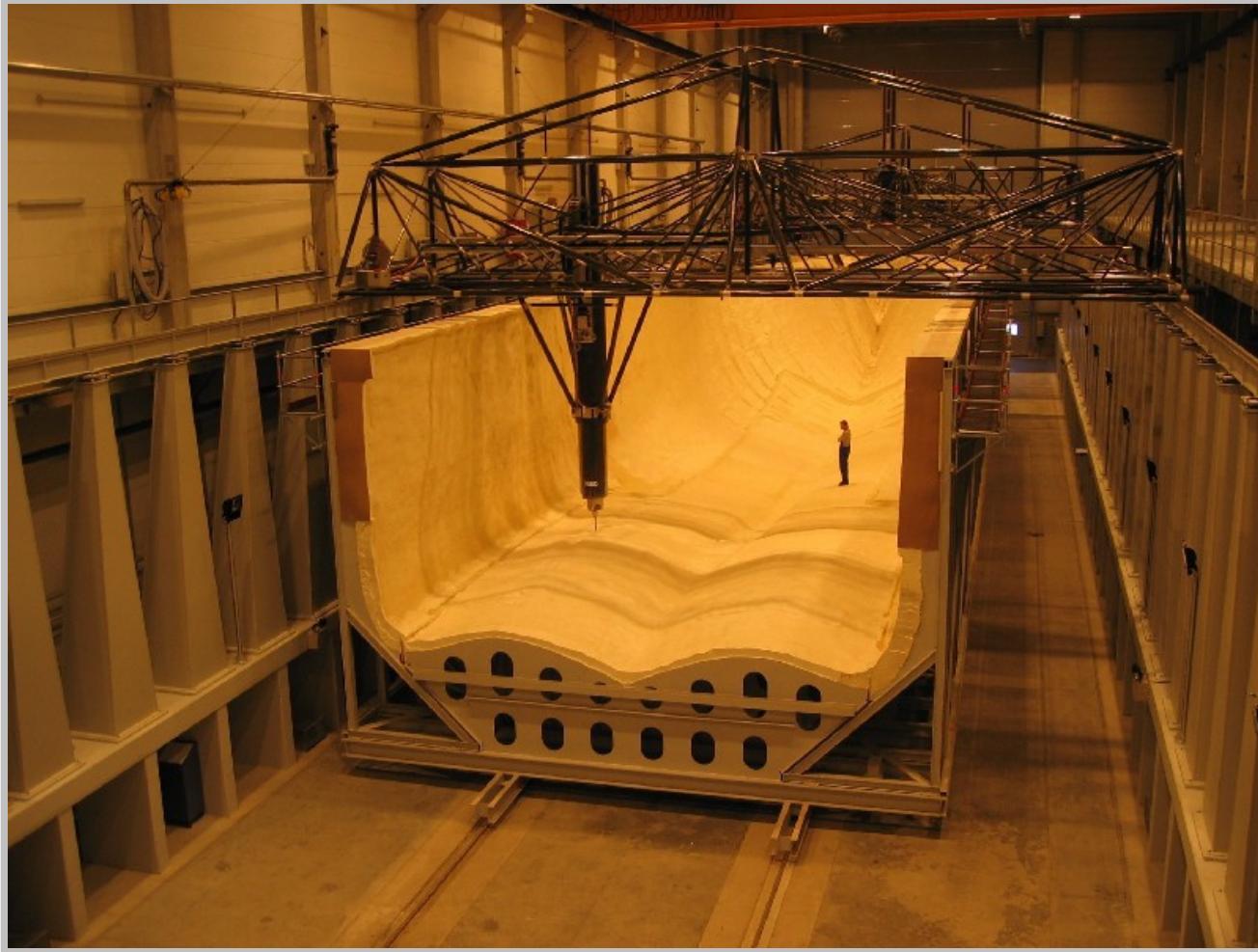
# CNC milling: 5-axis



An example: TN5, a 5-Axis Milling Machine.

Source: <http://youtu.be/vark2IBMGr0> <http://www.mdaprecision.com/>  
<http://www.fiveaxismachining.com/index.php/why-5-axis/> <http://www.shopbottools.com/mProducts/5axis.htm>

# CNC milling: big size!



Meet HSM-Modal. This modular and customizable milling machine can expand into a 12.5m wide, 4m tall, and 150m long giant.

Source: <http://www.wired.com/design/2012/06/cnc-mill-that-will-build-a-house/>

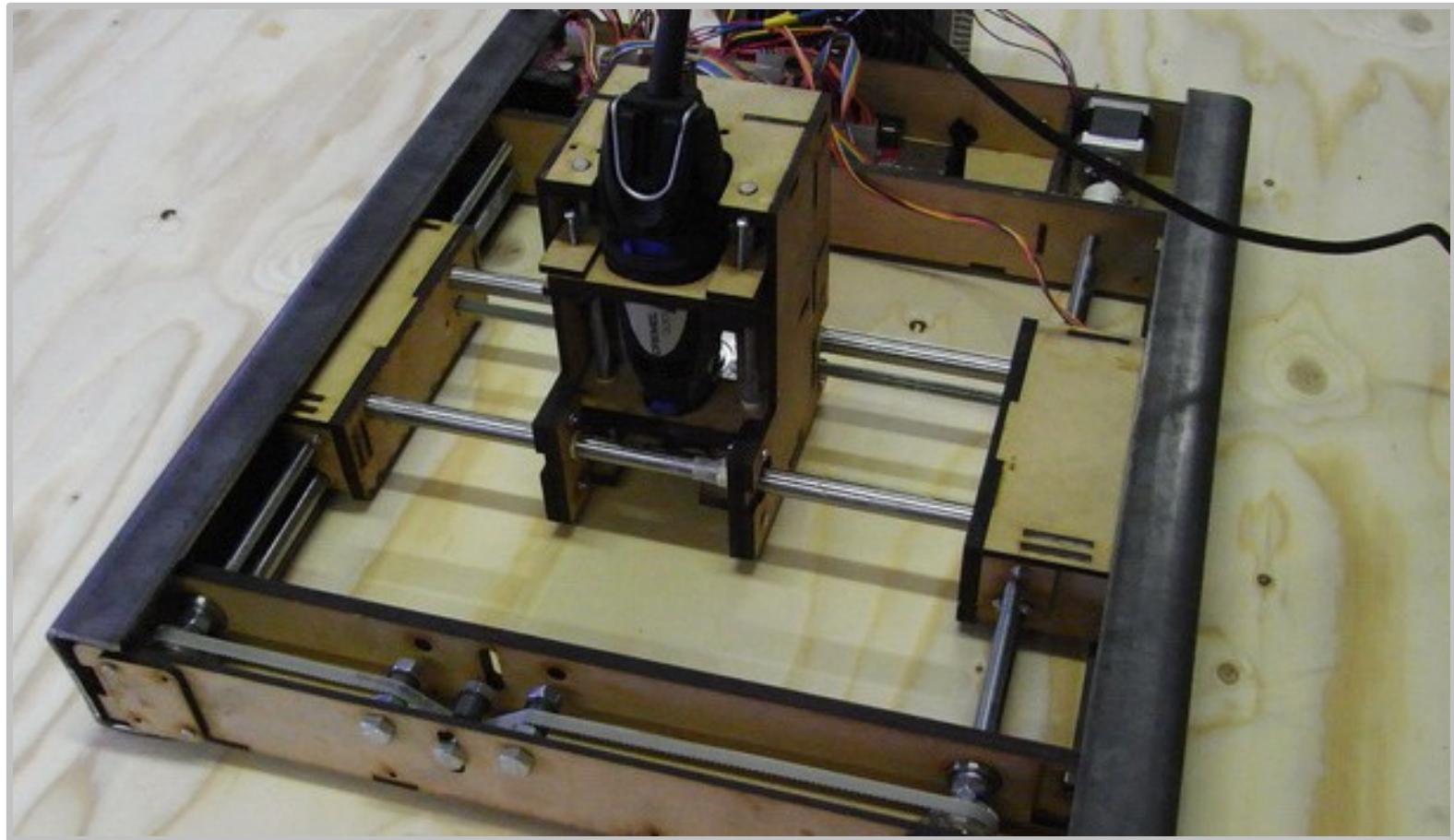
# Roland iModela: small, low-cost CNC milling



The iModela is a low-cost, easy-to-use desktop device that mills wax, foam, balsa wood and plastic materials. Max operation area: 86 x 55 x 26 mm

Source: <http://icreate.rolanddg.com/iModela/Global/English/about/index.html/>

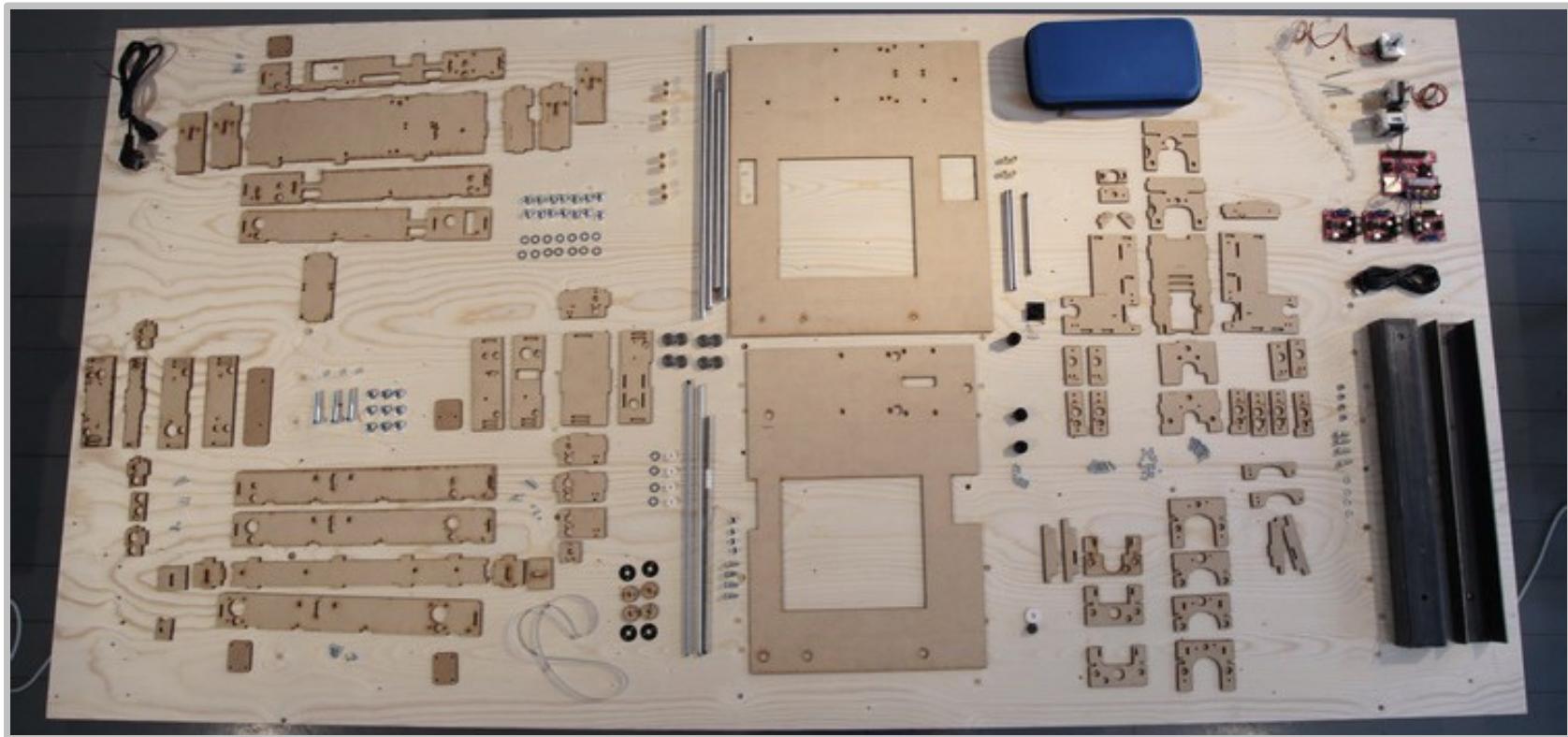
# MiniCNC: Open Source CNC milling



A desktop-size, open-source milling machine in kitform, built from lasercut parts: a computer-controlled Dremel with a 20 by 20 cm work surface.

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

# MiniCNC: Open Source CNC milling



A desktop-size, open-source milling machine in kitform, built from lasercut parts: a computer-controlled Dremel with a 20 by 20 cm work surface.

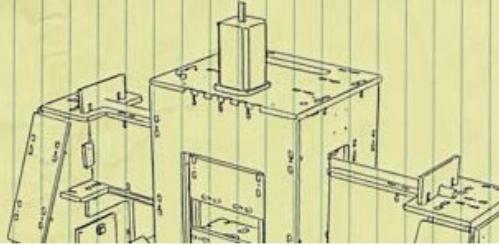
Source: <http://www.repairablemachines.com/>

# DIYLILCNC: Open Source CNC

# DIYLILCNC

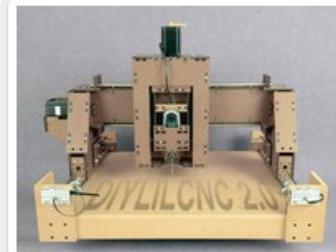
vers. 1.0.2

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**Kickstart v2.0!**

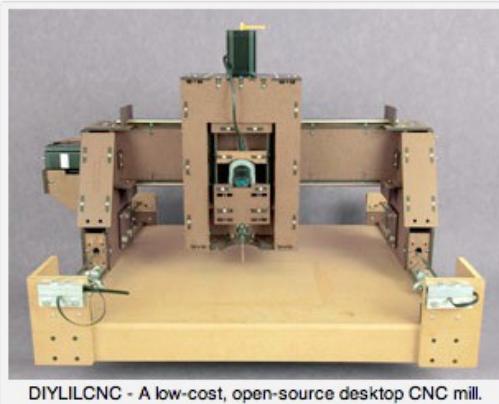


DIYLILCNC 2.0 - Open-source plans for a low-cost CNC mill.  
by DIYLILCNC  
We're preparing to release version 2.0 of our free, open-source plans for a robotic cutting machine that you can build yourself.

**Home**

The DIYLILCNC project is a free & open-source set of plans for an inexpensive, fully functional 3-axis CNC mill that can be built by an individual with basic shop skills and tool access.

CNC devices are used to fabricate physical objects with a high degree of precision. Some CNC devices, including the DIYLILCNC, feature a gantry-mounted cutting tool (like a router) that can move in two or more directions. The operation of the tool is controlled by a computer, which is tasked with translating a digital design into actual tool movement.



A free & open-source set of plans for an inexpensive, fully functional 3-axis CNC mill that can be built with basic shop skills and tool access.

Source: <http://diylilcnc.org/>

# Shapeoko: Open Source CNC

shapeoko

Home Blog Purchase Downloads Wiki Forum About

Shapeoko is now available through [inventables.com!](#)

Introduction to Shapeoko

Share More info

YouTube

An open source CNC milling machine that was over 700% funded on Kickstarter and that it is now also available on Inventables.com.

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

# 3 Axis CNC router built from Lego



Arthur Sacek has created a 3D CNC router built entirely from Lego Mindstorm robotics components.

Source: <http://blog.ponoko.com/2011/08/21/3-axis-cnc-router-built-from-lego/>  
<http://youtu.be/pX1c02XhMrg>

# Hexapod Robot CNC Router



A walking CNC router built using B.F.Hexapod with an additional floating pen attachment, and a utility to convert DXF files into commands.

Source: <http://youtu.be/quN37YskoaM?t=1m18s>  
<http://blog.ponoko.com/2008/11/11/articulated-cnc-robots-are-kind-a-scary/>

# And in our lab: Roland Modela MDX-20 (3 axis)

Imagine.

Roland®

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Inkjet Printers + Printer/Cutters    Vinyl Cutters + Print Trimmers    Rotary Engravers + Impact Printers    Benchtop Mills + 3D Scanners

## COMBO 3D SCANNING & MILLING



### MDX-15 & MDX-20 Portable Milling Machine and Scanner

Overview    Features    Specifications    Accessories    Brochure    Technical Support

These small milling machines, capable of scanning and milling, are ideal for a variety of product design tasks, including reverse modeling, rapid prototyping, jewelry and model making, and small lot production.



**Brochure**

 Free brochure available in print or download form.

 Choosing The Right RP System. Free brochure available in print or download form.

Download Prototyping White Paper

Max operation area:  
203.2 mm (X) x 152.4 mm (Y) x 60.5 mm (Z)

Source: <http://www.rolanddga.com/products/scanners/mdx15/>



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# CNC, but not only Milling: other computer controlled tools

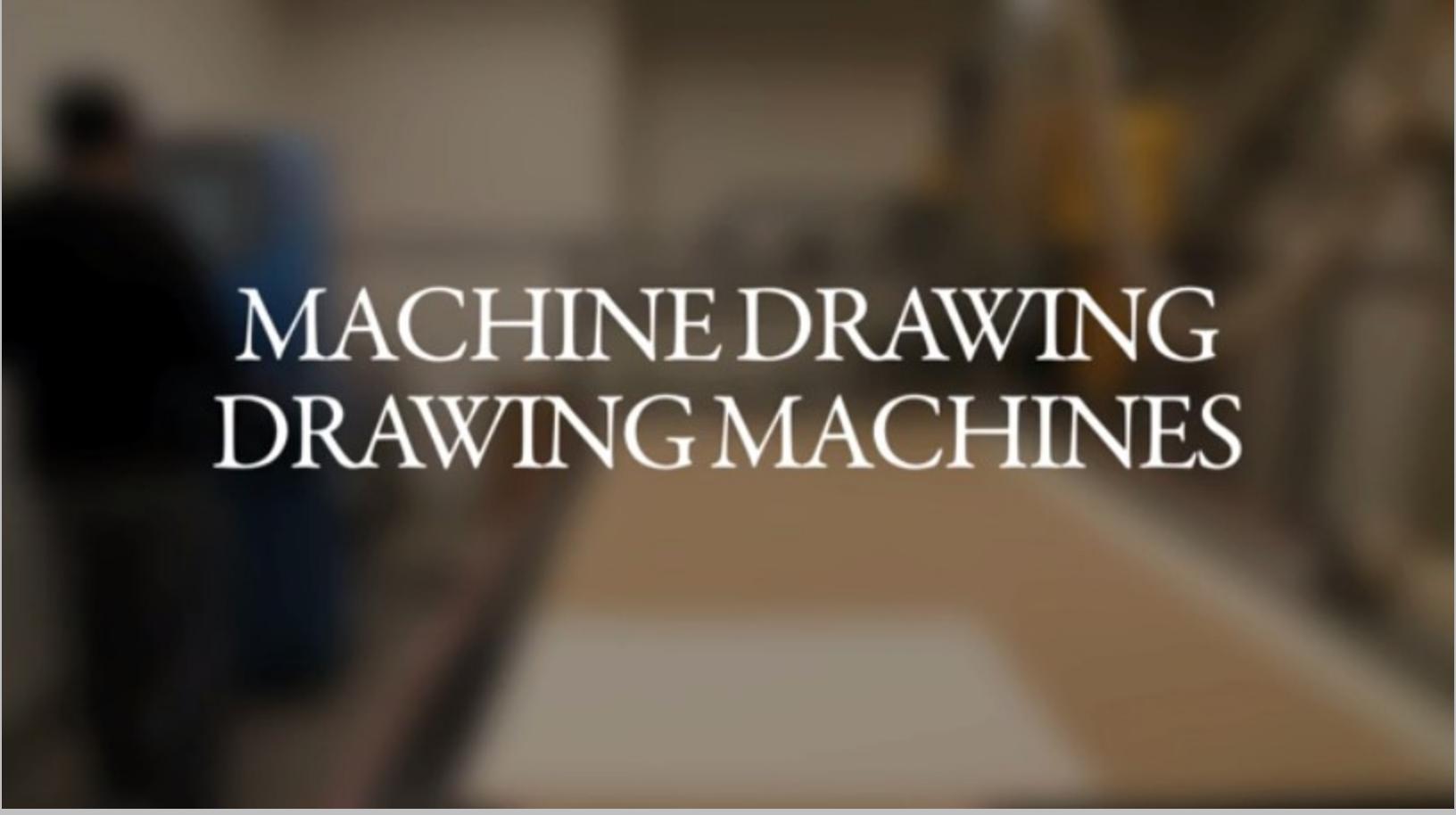
# CNC milling the music



Valse Automatique is a design performance made by translating music to form over the use of a kuka industrial robot.

Source:<http://www.creativeapplications.net/processing/valse-automatique-symbiosis-between-humans-and-technology-processing-rhino/>

# CNC milling drawing



MACHINE DRAWING  
DRAWING MACHINES

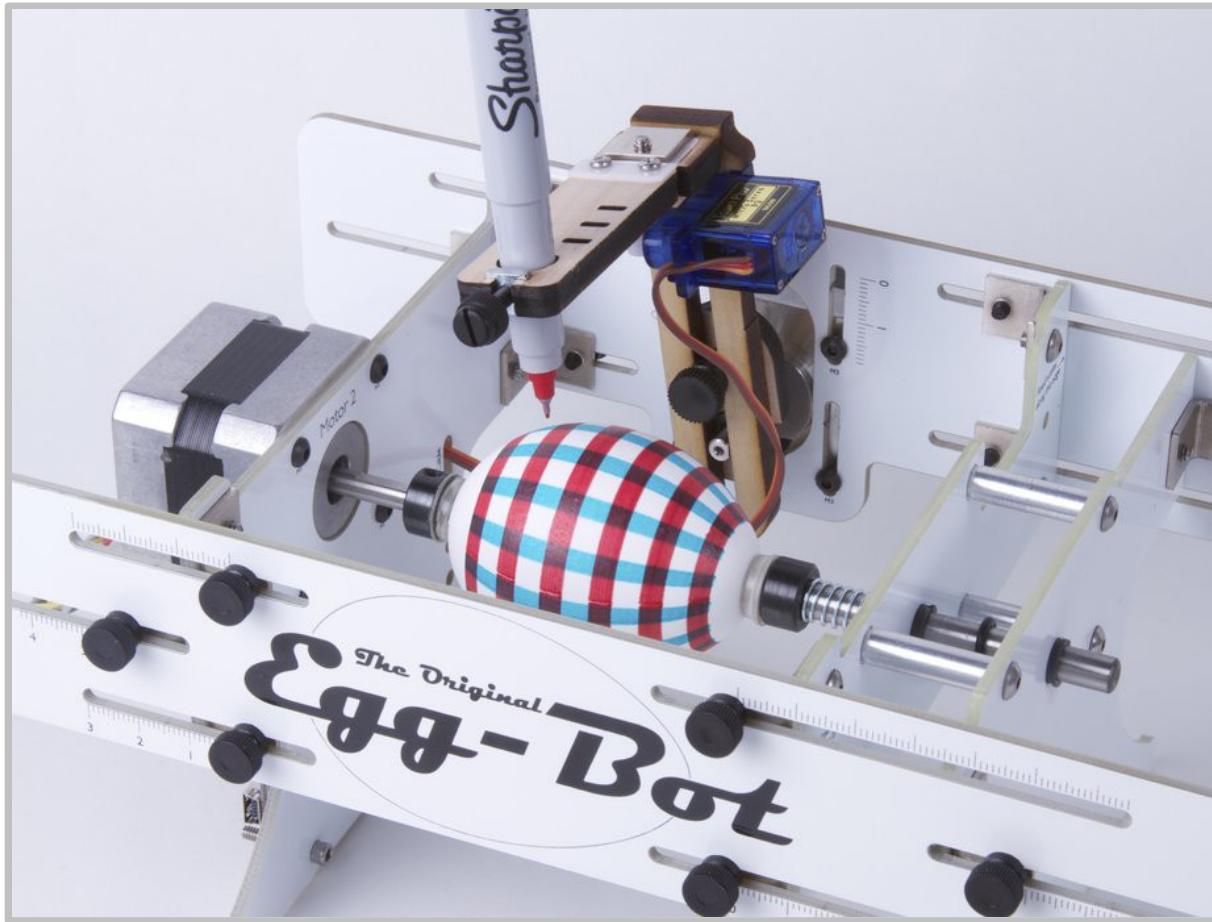
---

In which twelve drawings of historical drawing machines are drawn by a computer numerical controlled machine.

Source: <https://vimeo.com/39951217>

<http://www.designboom.com/weblog/cat/10/view/20427/cnc-historical-drawing-machine.html>

# Egg-bot

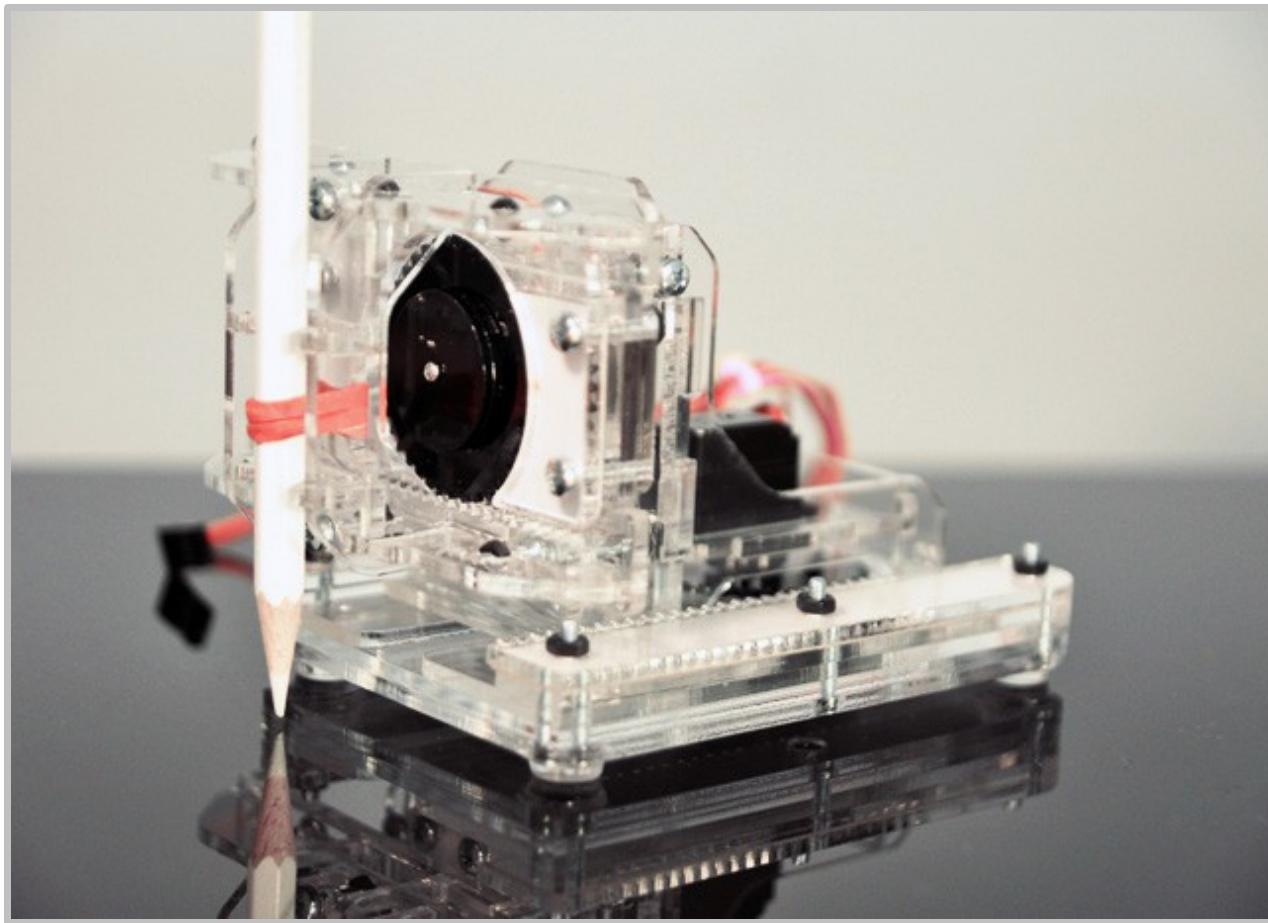


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“My experience, perception and digital information  
(bits) shape this exact material and its values (atoms)”

Source: <http://evilmadscience.com/productsmenu/tinykitlist/171-egg-bot>  
<http://egg-bot.com/>

# Piccolo

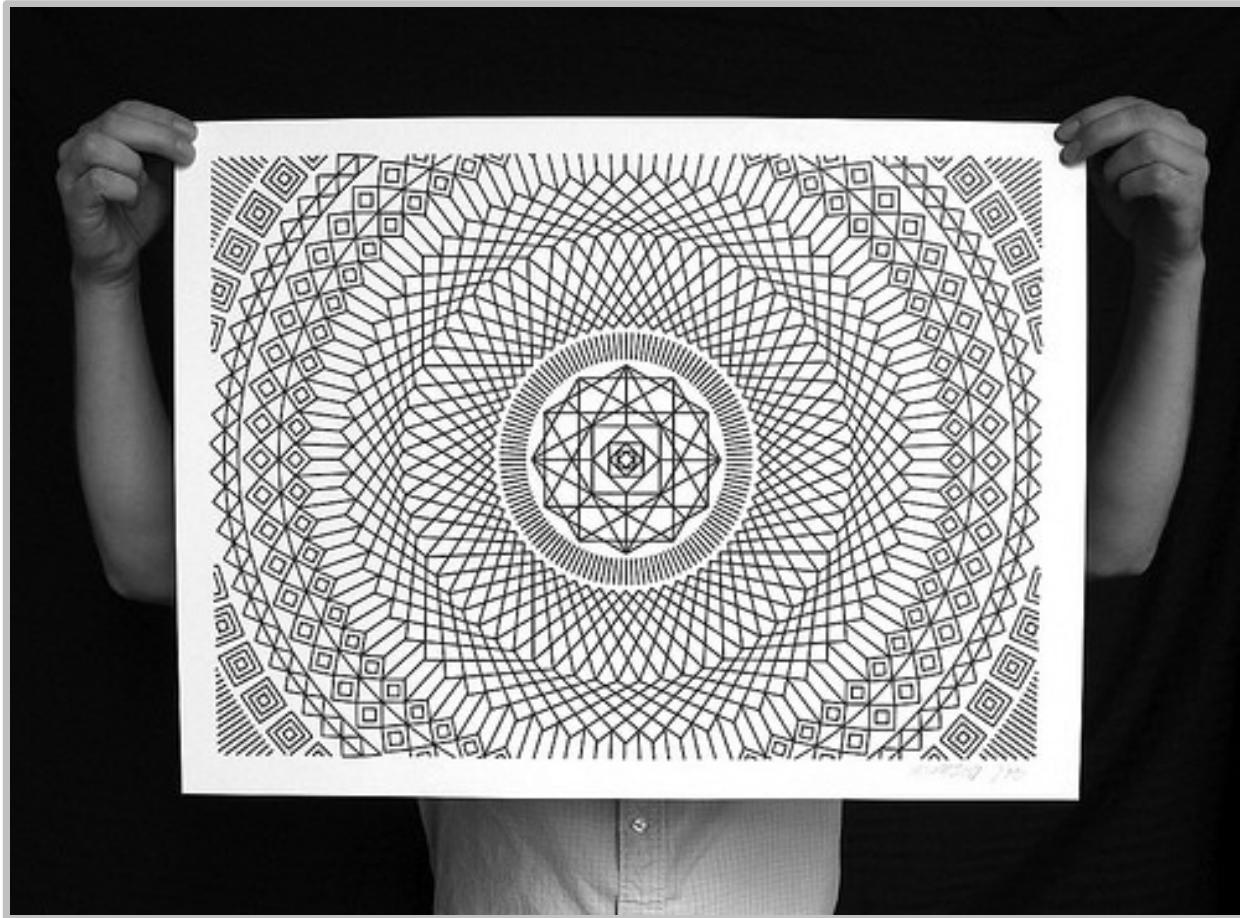


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“My experience, perception and digital information  
(bits) shape this exact material and its values (atoms)”

Source: <http://diatom.cc/piccolo>  
<https://vimeo.com/36869769>

# MWM graphics/aarn: CNC drawing series

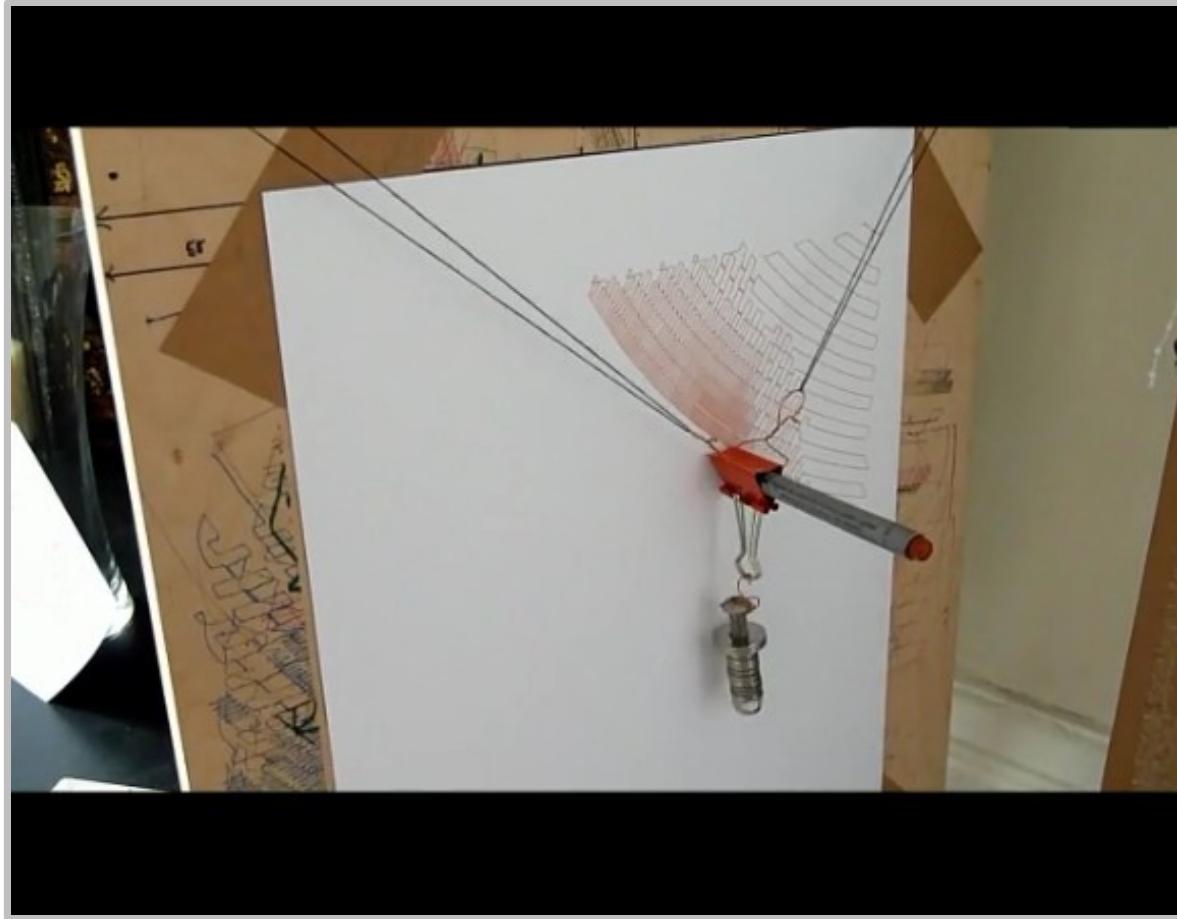


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3-axis CNC machine retrofitted with a special fixture - which holds a marker and mimics typical hand pressure during the act of drawing.

Source: <http://44rn.com/post/7774864814/numericallycontrolledseries>

# Polargraph Drawing Machine

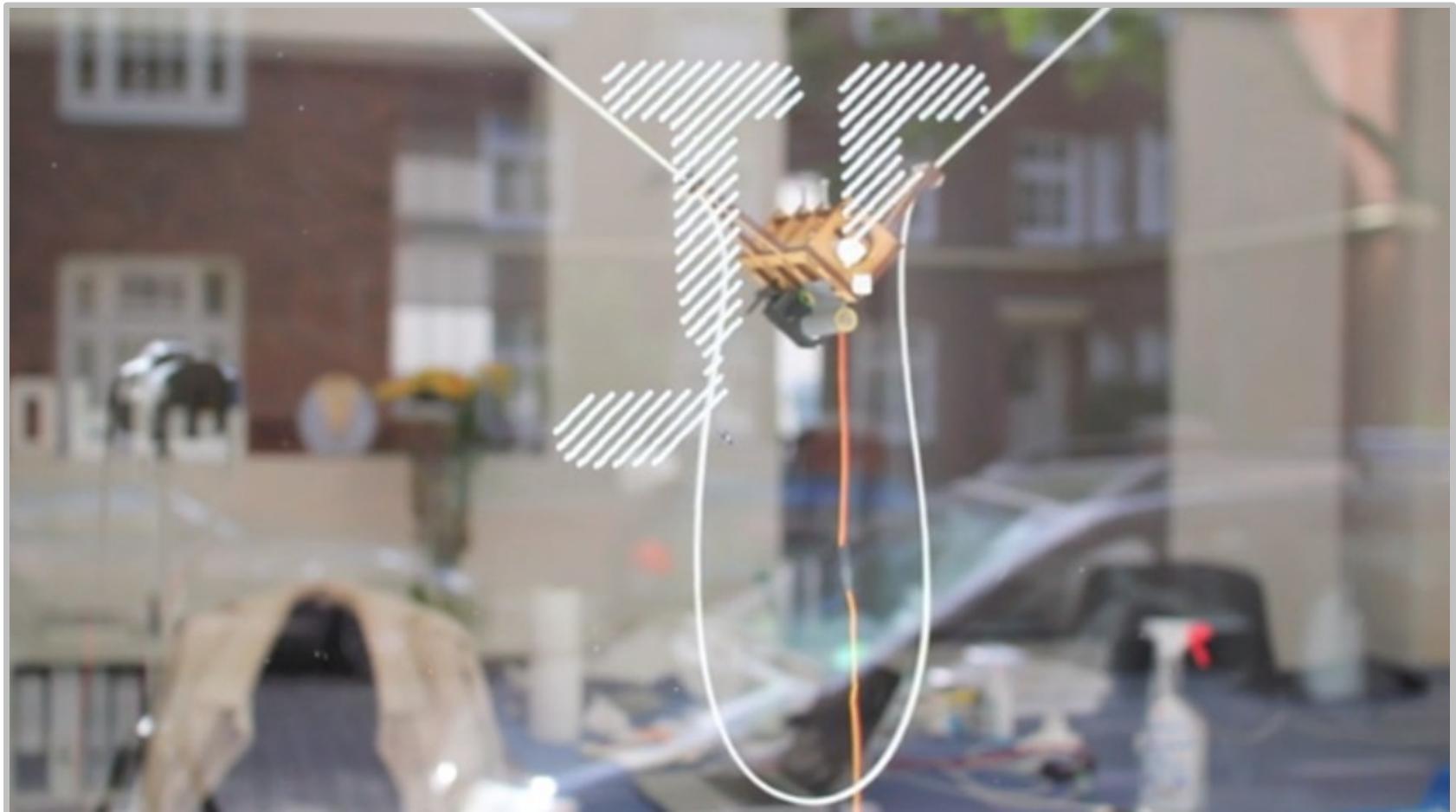


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Sandy Nobel's Polargraph uses a dual-polar coordinate system instead of the standard cartesian.

Source: <http://blog.makezine.com/2011/09/27/polargraph-drawing-machine/>  
<https://vimeo.com/24647023> <http://www.instructables.com/id/Polargraph-Drawing-Machine/>

# Der Kritzler Drawing Machine

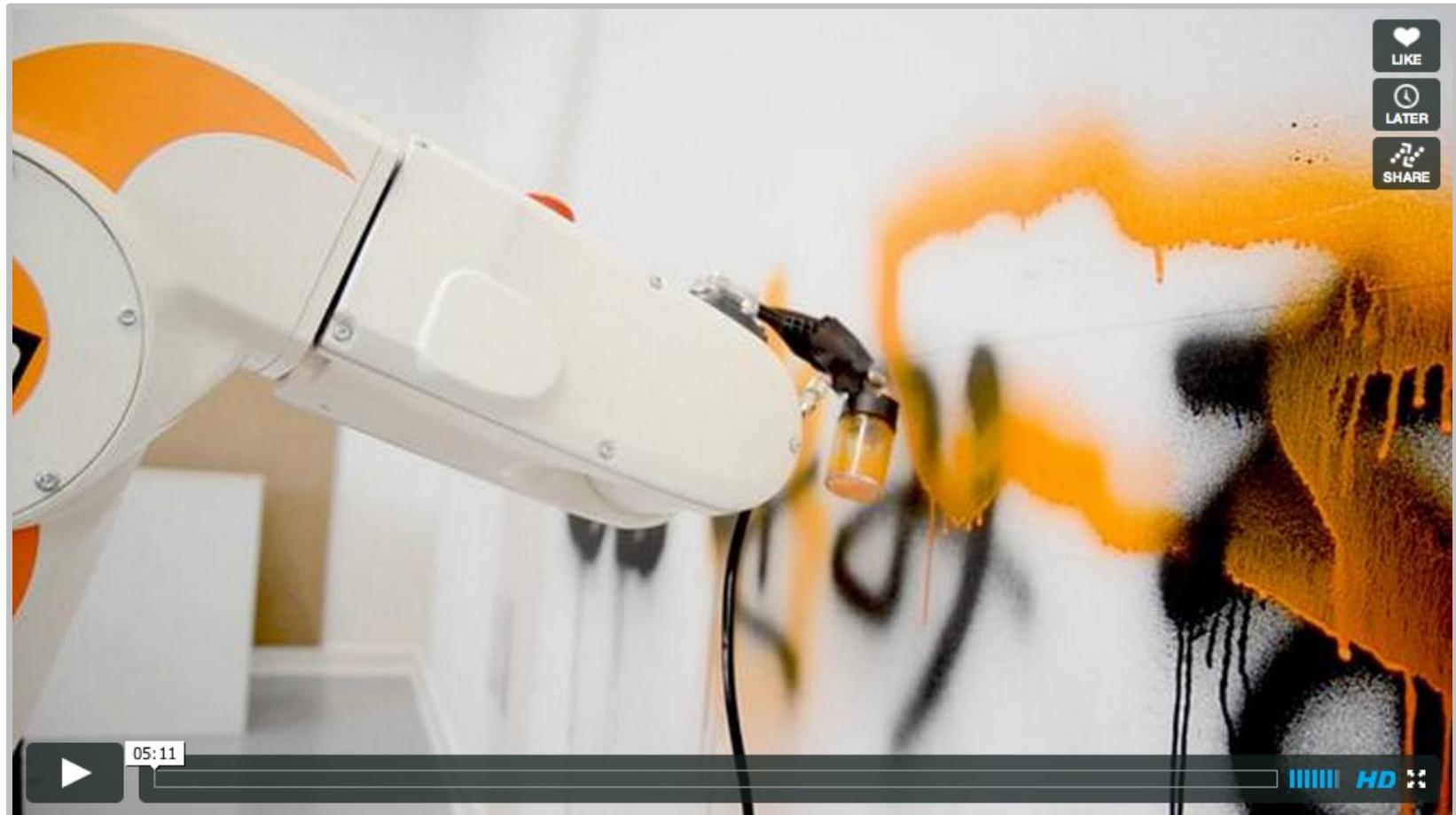


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2D scribbling machine, drawing directly on a window.

Source: <http://tinkerlog.com/2011/09/02/der-kritzler/>  
<https://vimeo.com/28003302>

# Robot Masterclass

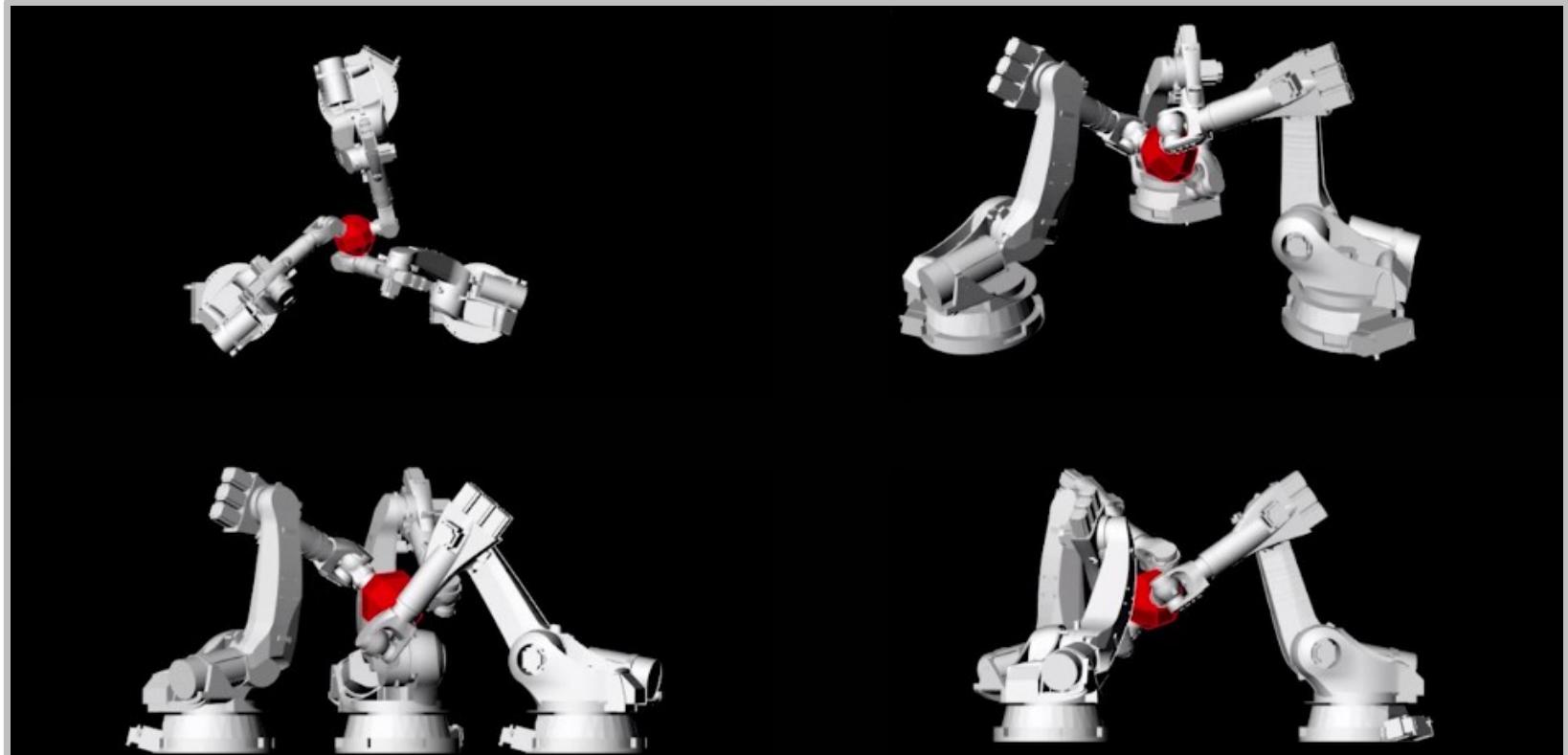


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Using an Arduino board, the KUKA robot interfaced with the spraygun, allowing designs that consist of multiple strokes.

Source: <https://vimeo.com/30506602>  
<http://www.robotsinarchitecture.org/>

# And a plugin for Grasshopper



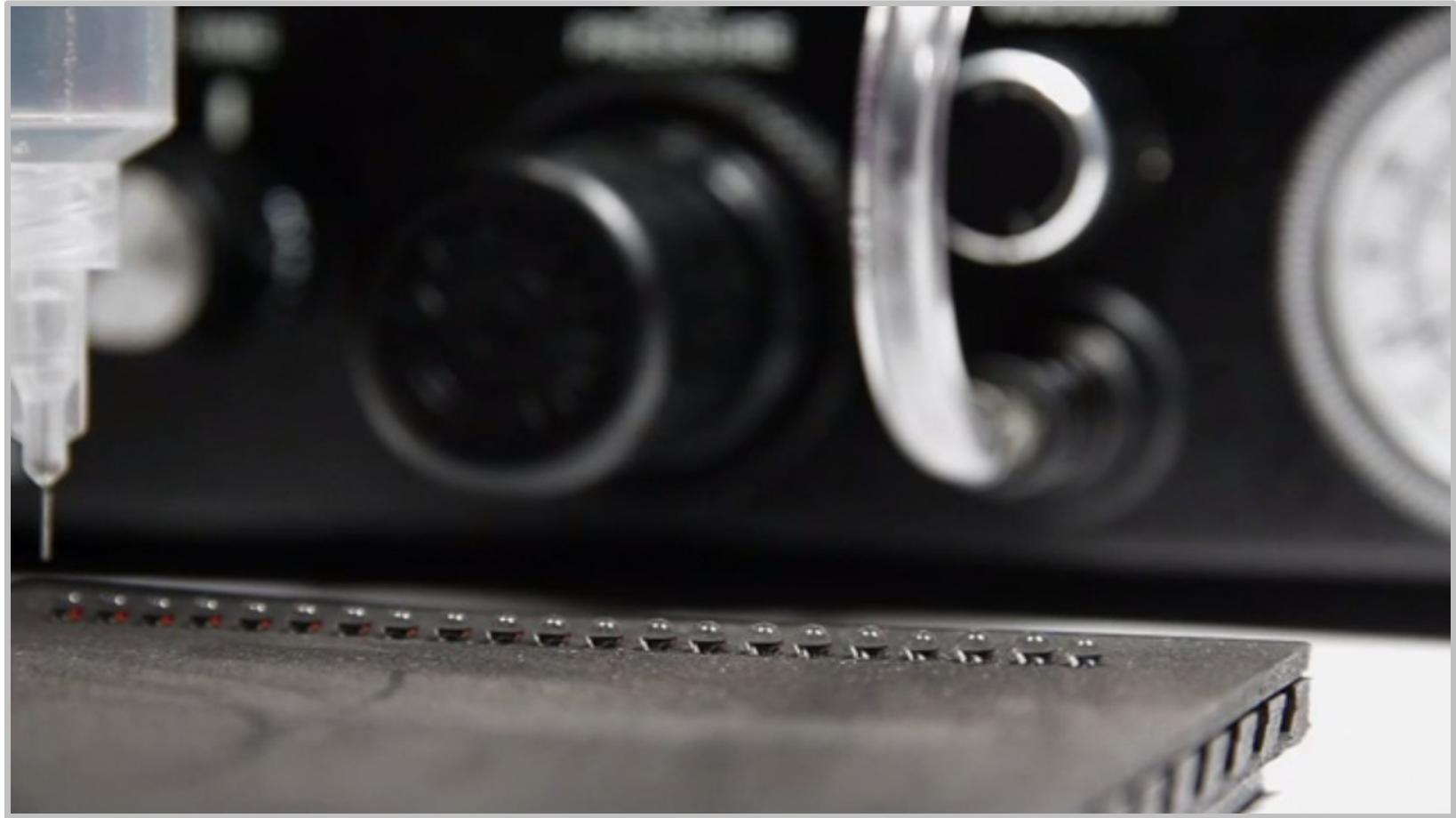
## Multiple robot simulation

Simulate multiple robots by locking each kinematic component after setting it up

KUKA|prc enables you to program industrial robots directly out of the parametric modelling environment, including a full kinematic simulation of the robot.

Source: <http://www.robotsinarchitecture.org/kuka-prc>  
<https://vimeo.com/37480161>

# Positioning systems I - falling objects



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A custom made machine that adds drops of water onto a special textured surface. Each drop forms into an almost perfect sphere through the surface tension.

Source: <https://vimeo.com/24491037>



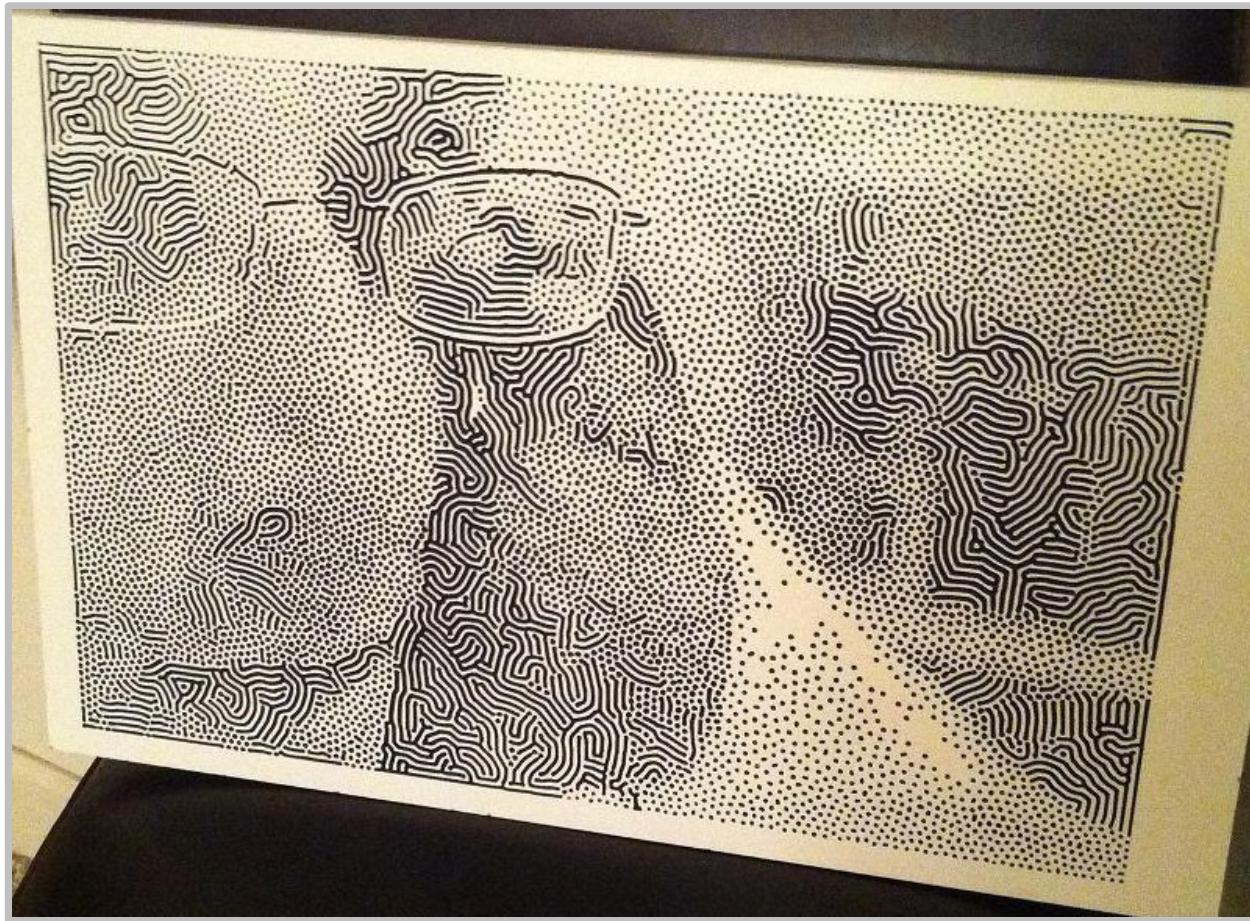
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03.

Examples:

what you can do with a CNC milling  
machine

# Create halftones images with CNC Milling



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Jason Dorie has created a couple of Windows applications that allow people to create halftones images for CNC routing from ordinary image files.

Source: [http://jasondorie.com/page\\_cnc.html](http://jasondorie.com/page_cnc.html)

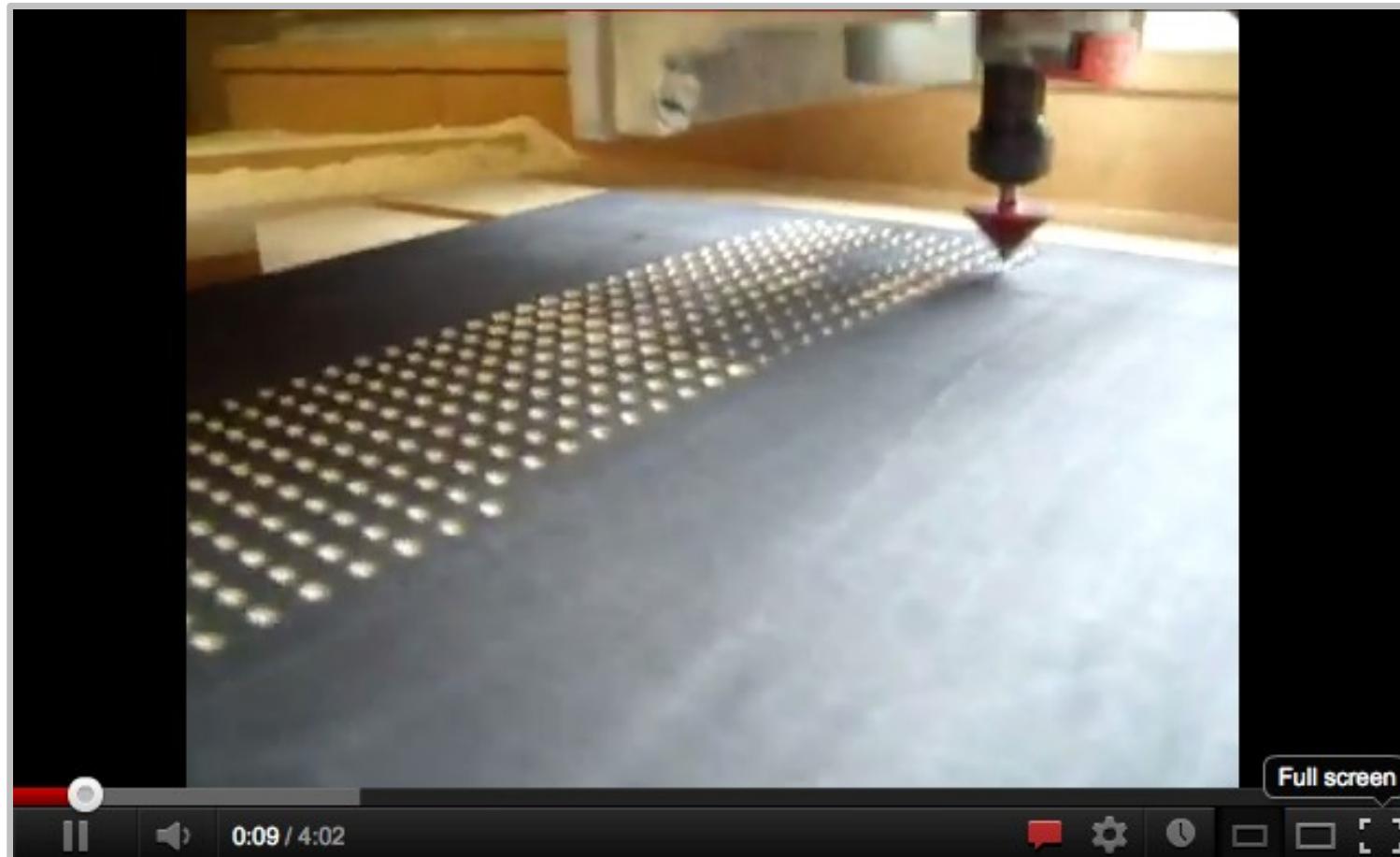
# Create halftones images with CNC Milling



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Source: <http://youtu.be/xoJDTPRqI6o>

# Create halftones images with CNC Milling



A similar example, from Finland...

# CNC Milled furniture: flat plack



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PANELS.02&03 - Chair & table by Sebastien Wierinck.

Source: [http://sebastienwierinck.com/html/SW\\_WORK\\_DF.html](http://sebastienwierinck.com/html/SW_WORK_DF.html)

# CNC Milled bike: flat plack



Winning second prize from the L'Argus Design Competition for his Roll Bike Concept design, Nicolas Belly has taken the children's balance bike to another level.

Source: <http://blog.ponoko.com/2010/01/28/flat-pack-bike/>

# CNC Milled and stitched furniture



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Stitched collection by Tord Boontje

Source: <http://blog.ponoko.com/2011/08/06/tord-boontje-stitched-collection/>  
<http://tordboontje.com/>

# CNC Milled furniture



Gareth Neal has produced a few exceptional pieces that straddle the divide between art and design, furniture and sculpture.

Source: <http://blog.ponoko.com/2010/02/21/classic-cuts-and-cnc-craftsmanship/>

# CNC Milled furniture



---

The design of the Laszlo Files are based on new possibilities afforded by the use of computer numerically controlled (CNC) technology.

Source: <http://blog.ponoko.com/2009/06/03/office-da-pump-serious-cnc-assisted-design/>

# Textures: experiment with density and porosity



---

“Albeflex BL Special” is designed to be lightweight, self-supporting and capable of taking advantage of CNC driven digital fabrication techniques.

Source: <http://blog.ponoko.com/2009/12/13/experiments-in-porosity/>  
<http://dudye.com/experimenting-with-porosity>

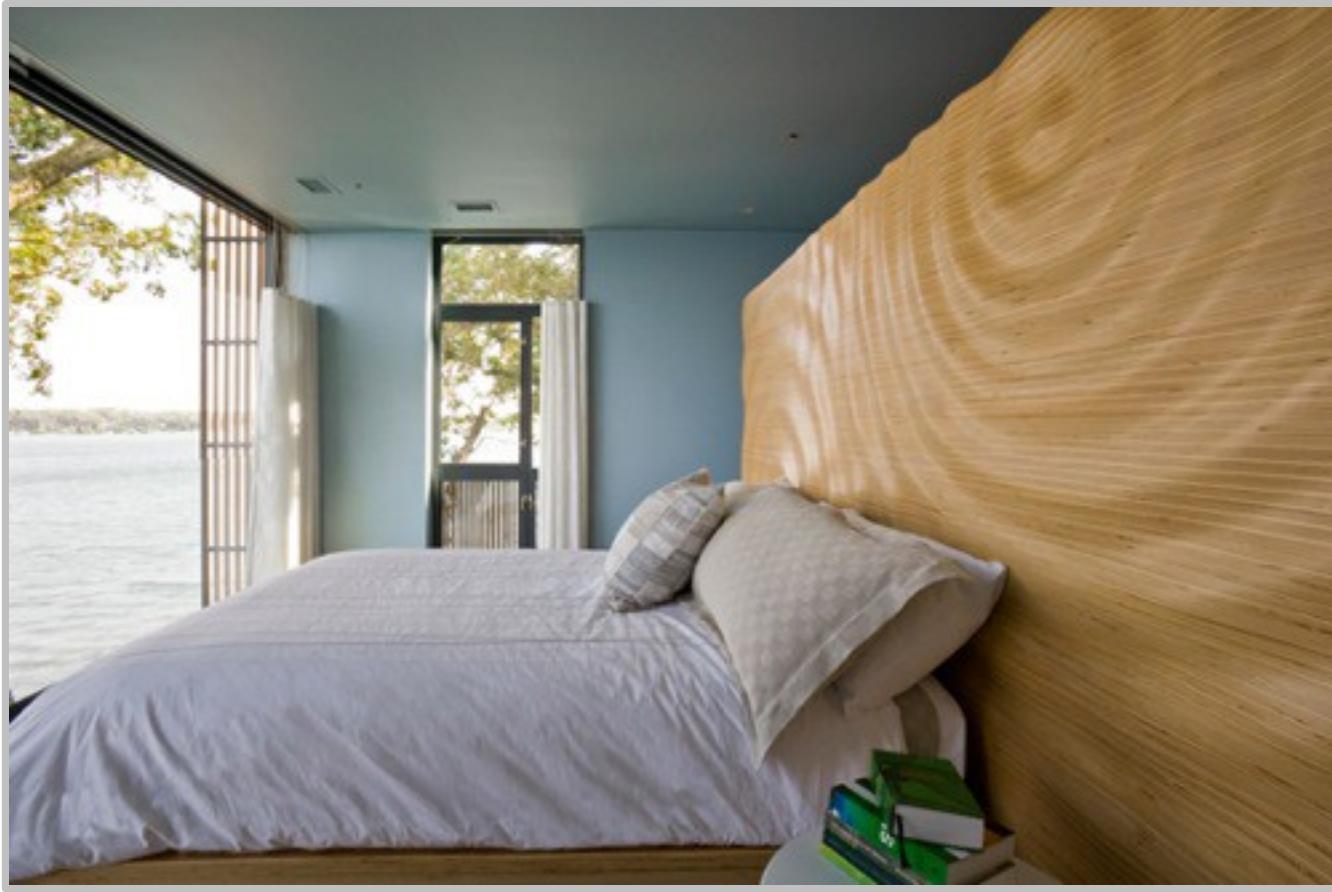
# CNC Milled interior design



Working with natural materials, March Studio has formed a sculptural retail space for an artisan bakery in Melbourne, Australia.

Source: <http://www.frameweb.com/news/d-chirico-bakery>

# CNC Milled interior design

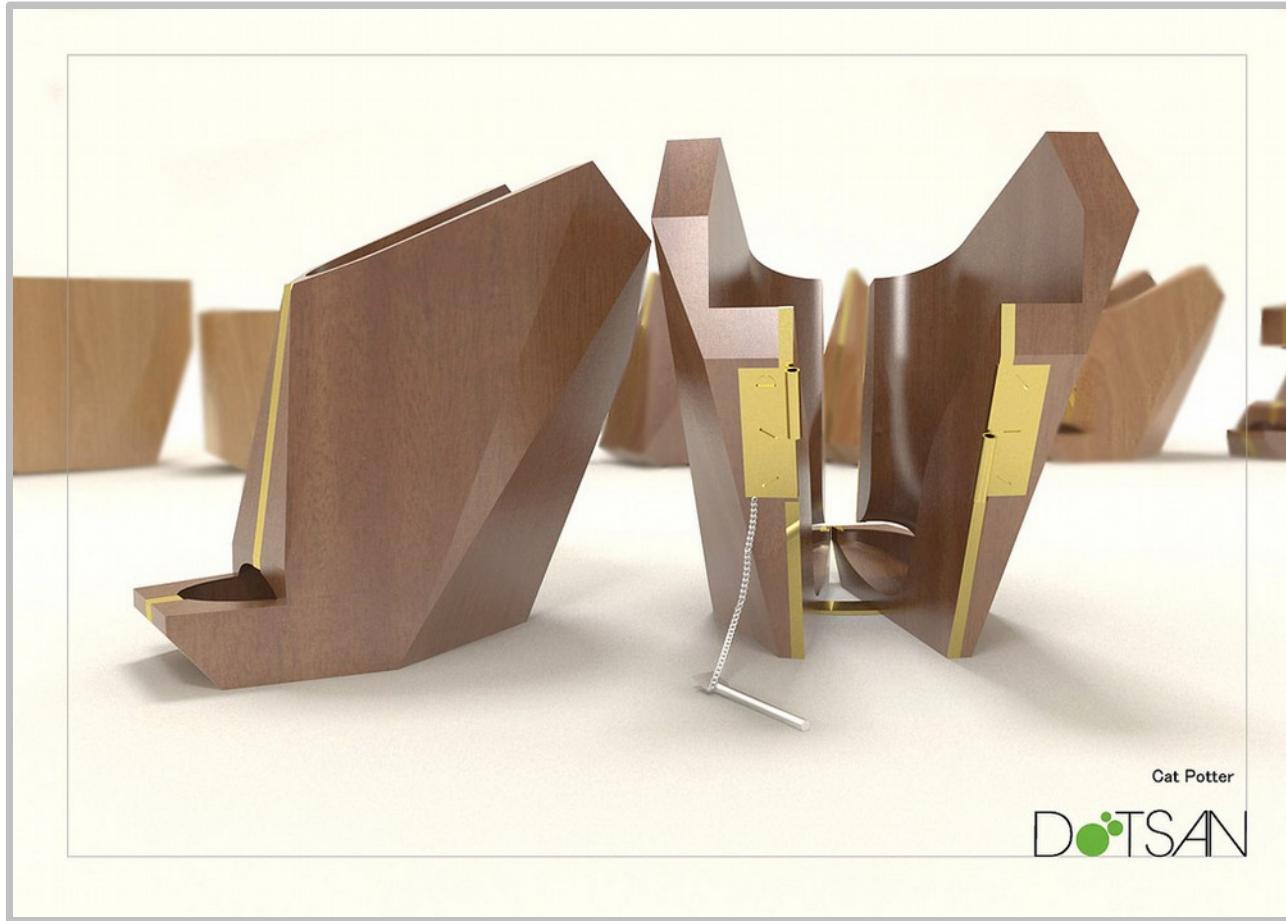


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The piece is essentially a storage cabinet lifted 12" above the floor. The architect studied the form of water ripples from several photographs of the lake.

Source: <http://blog.ponoko.com/2009/05/25/lake-cabinet-further-cnc-wall-madness/>  
<http://blog.ponoko.com/2012/03/12/cnc-milling-waves/>

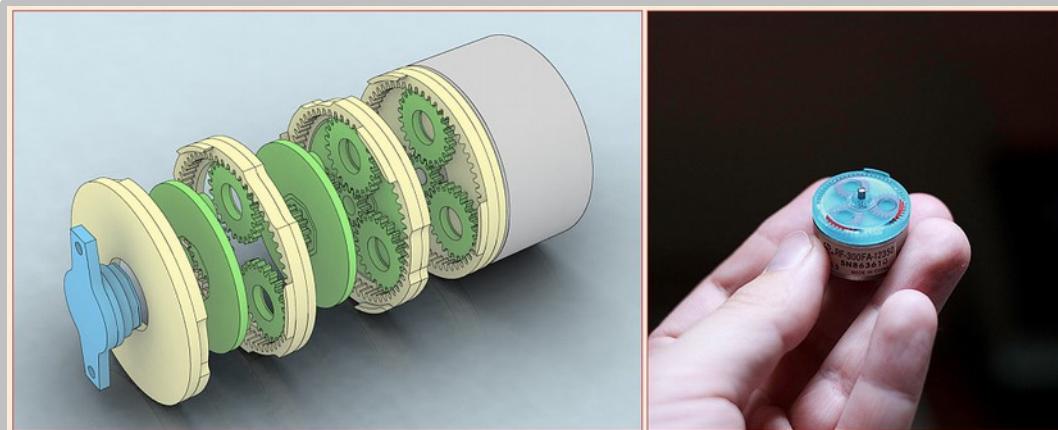
# CNC Milled shoes



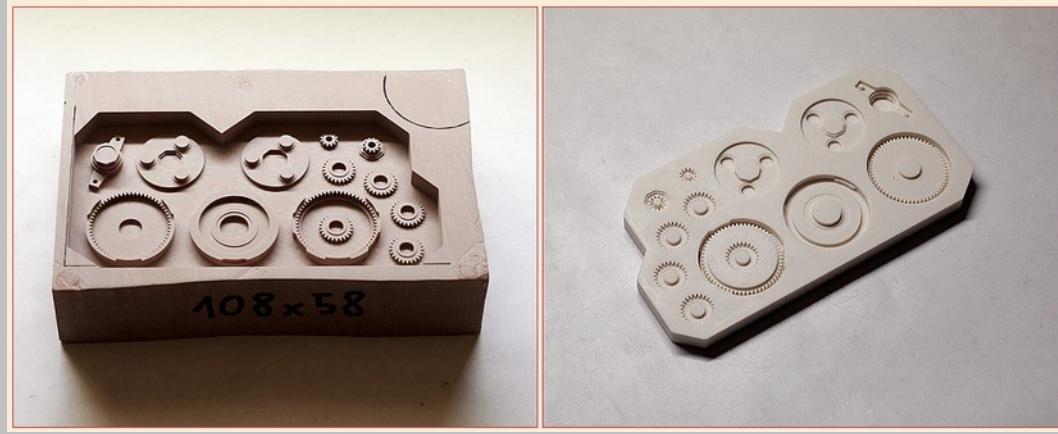
Experimental shoes by designer Cat Potter were shaped from solid blocks of wood with a 3-axis CNC milling machine.

Source: <http://www.flickr.com/photos/42746980@N02/6673839607/in/pool-375602@N23/lightbox/>  
<http://blog.ponoko.com/2012/01/11/cnc-milled-wooden-shoes/>

# CNC Milled molds for mechanical parts



Well, this time around, it worked out [pretty much flawlessly](#):



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XXX

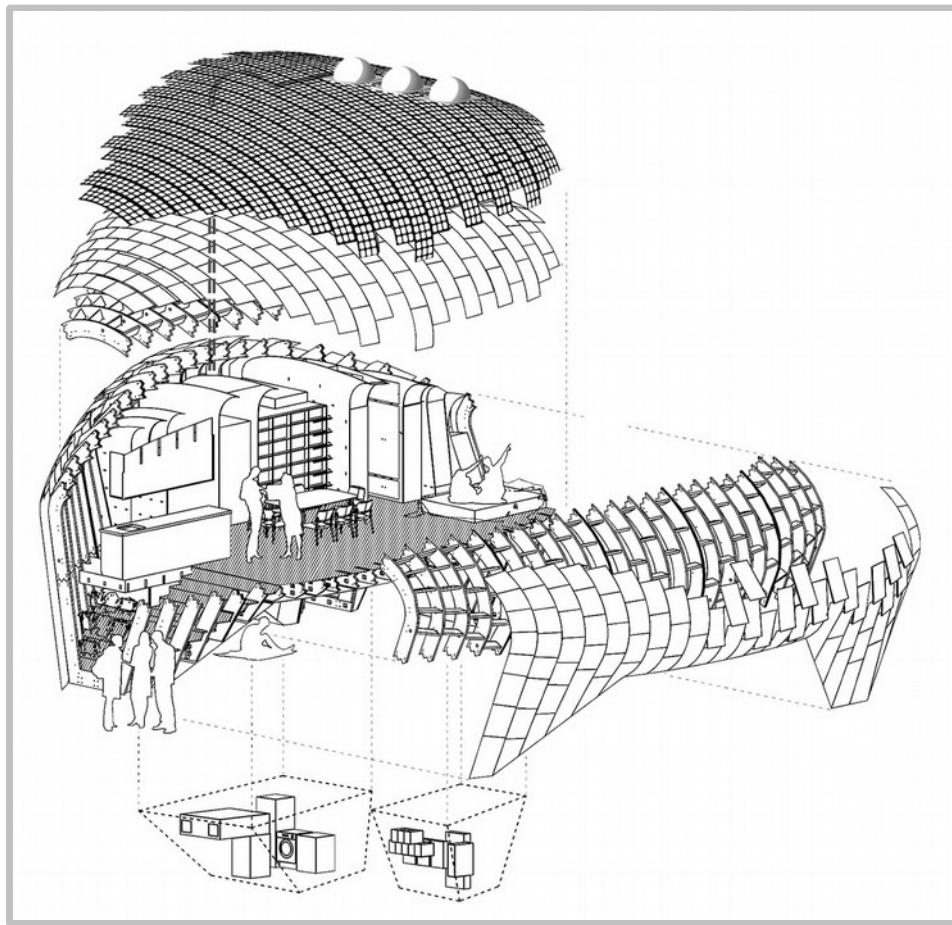
# CNC milled products



Blocks of solid maple are milled in two separate halves and joined together with an accentuated “parting line”, articulating the profile of the shapes.

Source: <http://blog.ponoko.com/2009/05/07/cnc-vases-by-paul-loebach/>

# FabLab House



The Fab Lab House is developed on a network of fablabs using CNC machines to design and produce houses than can be customizable.

Source: <http://www.fablabhouse.com/en/la-forma-sigue-la-energia/>



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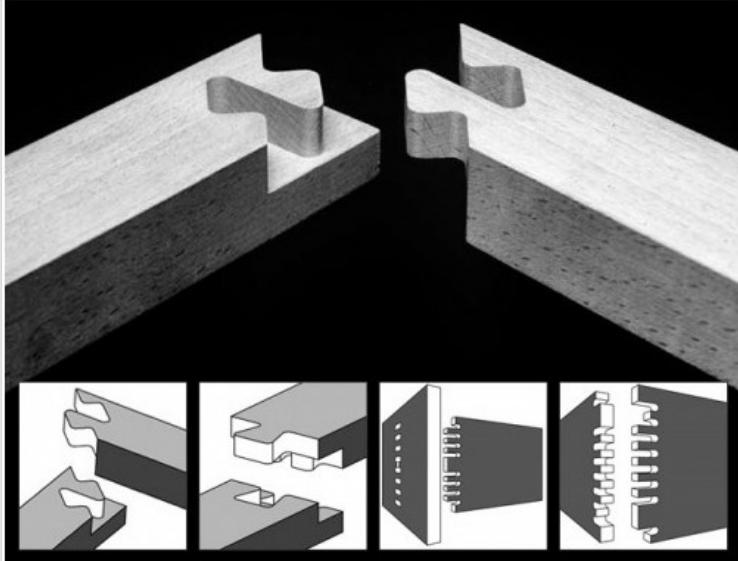
# Design techniques: how to design for CNC milling machines

# Digital wood joints ready to use

**Flexible Stream**  
OPEN DESIGN SOURCE

Free Design What for Submit Help

**50 DIGITAL WOOD JOINTS**  
Jochen Gros



**Download this Design**

- Digital Wood Joints (4 examples)
- Instructions 4 Examples
- [Download all Woodjoints](#)

Some rights reserved:  
[CC BY-NC-SA 3.0](#)

**Parts**  
No parts available

**Contact Designer**

Jochen Gros  
[www.movicons.com](http://www.movicons.com)

---

A library of 50 wood joints in digital format available for download and use in your project.

Source: <http://www.flexiblestream.org/Digital-Wood-Joints-001.php>

# Digital wood joints ready to use

**Make:** Blog Magazine Projects Reviews Shop

Hot Topics: Kids Arduino 3D Printing Computers & Mobile Craft Raspberry Pi

Home / Desktop Manufacturing / CNC / CNC Panel Joinery Notebook

## CNC Panel Joinery Notebook

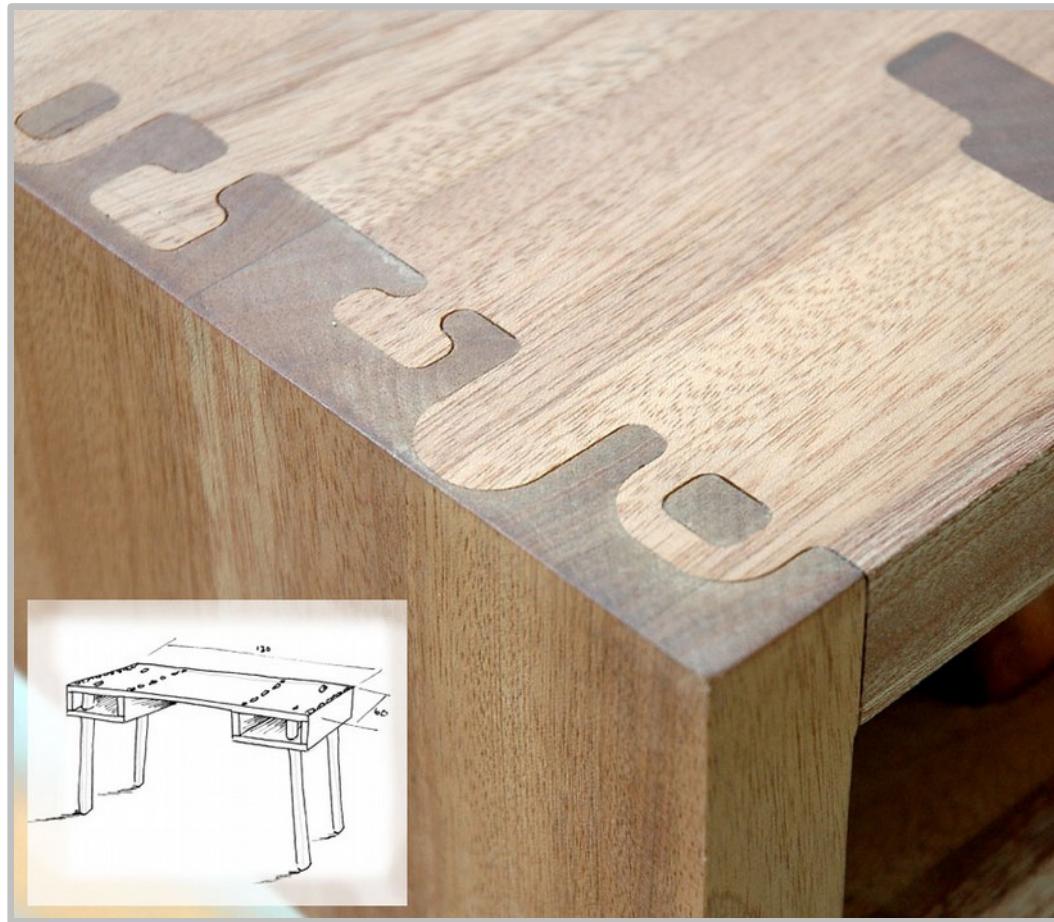
By Sean Ragan, 2012/04/13 @ 9:00 am

The image displays several digital wood joint designs and their corresponding physical prototypes. The top row features a 'T' joint and a 'K' joint. The middle row shows two small, interlocking puzzle-piece joints. The bottom row includes a wavy joint and a Y-shaped joint. These joints are designed to be cut out of wood using a CNC machine.

More information and tutorials..

Source: <http://blog.makezine.com/2012/04/13/cnc-panel-joinery-notebook/>

# Wood joints: they don't have to be boring



*Joints* by Tineke Beunders and Nathan Wierink (ontwerpduo) takes advantage of the precision in digital fabrication for an entire mahogany desk.

Source: <http://blog.ponoko.com/2009/05/31/ontwerpduo%E2%80%94fun-studio/>

# CNC Simulator

The screenshot shows the homepage of the CNC Simulator website. At the top, there is a large logo with the text "CNC SIMULATOR" and a gear icon. Below the logo, a banner reads "It is here! Download today! Your virtual workshop... CncSimulator Pro!". To the left, a sidebar contains a "Main Menu" with links to Home, About the CncSimulator, Petrol station, FAQ, Forum, Download, Sign Up, Order, CncSimulator Blog, Online Help, Getting Started Tutorial, Privacy Policy, and License agreement. Another section titled "Who are you?" lists options: A CNC programmer at a company, A hobby CNC programmer, A CNC student, A CNC teacher, A CNC retailer, and Other. On the right side, there is a "Login" form with fields for Username and Password, a "Remember Me" checkbox, and a "Login" button. Below the login form are links for "Forgot your password?", "Forgot your username?", and "Login with Facebook". A statistics box shows "670095" total visitors with breakdowns for Today (876), Yesterday (1918), This month (35608), and Last month (71131). At the bottom, there are sections for "News!", "Latest version", and "Future versions". The main content area features several screenshots of the CNC simulation software interface, showing a 3D model of a machine tool and a workpiece being machined.

The idea of the new CncSimulator Pro is to provide the machining industry with a contemporary competent Fanuc inspired CNC ISO simulator.

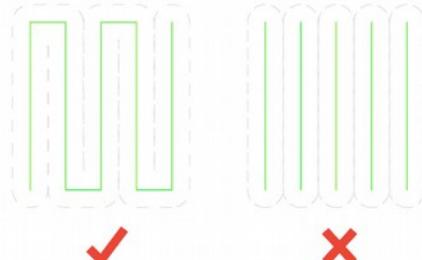
Source: <http://www.cnccsimulator.com/>

# Some suggestions for CNC Routing

**Pocketing lines should be joined where possible.**

A continuous line (red, green, magenta) is better than a series of disconnected shorter lines. Every time the machine starts a new path/line it has to move to the start of the line, plunge into the material and then move along the line. Repeating this process over and over is not ideal. The edge of your pocket will not be as clean as it will be if you use a continuous line.

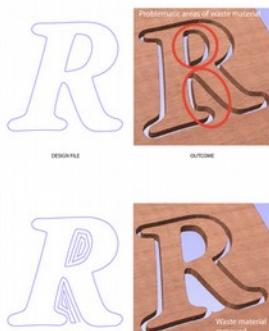
Also you can't guarantee which order the router will cut a lot of short disconnected lines. It is possible that it will leave a middle line until last leaving a thin, unstable piece of material that has the potential to break off and damage your job.



Find out more about pocketing and how to remove areas of material.

**Small areas of waste need extra cut lines to remove them.**

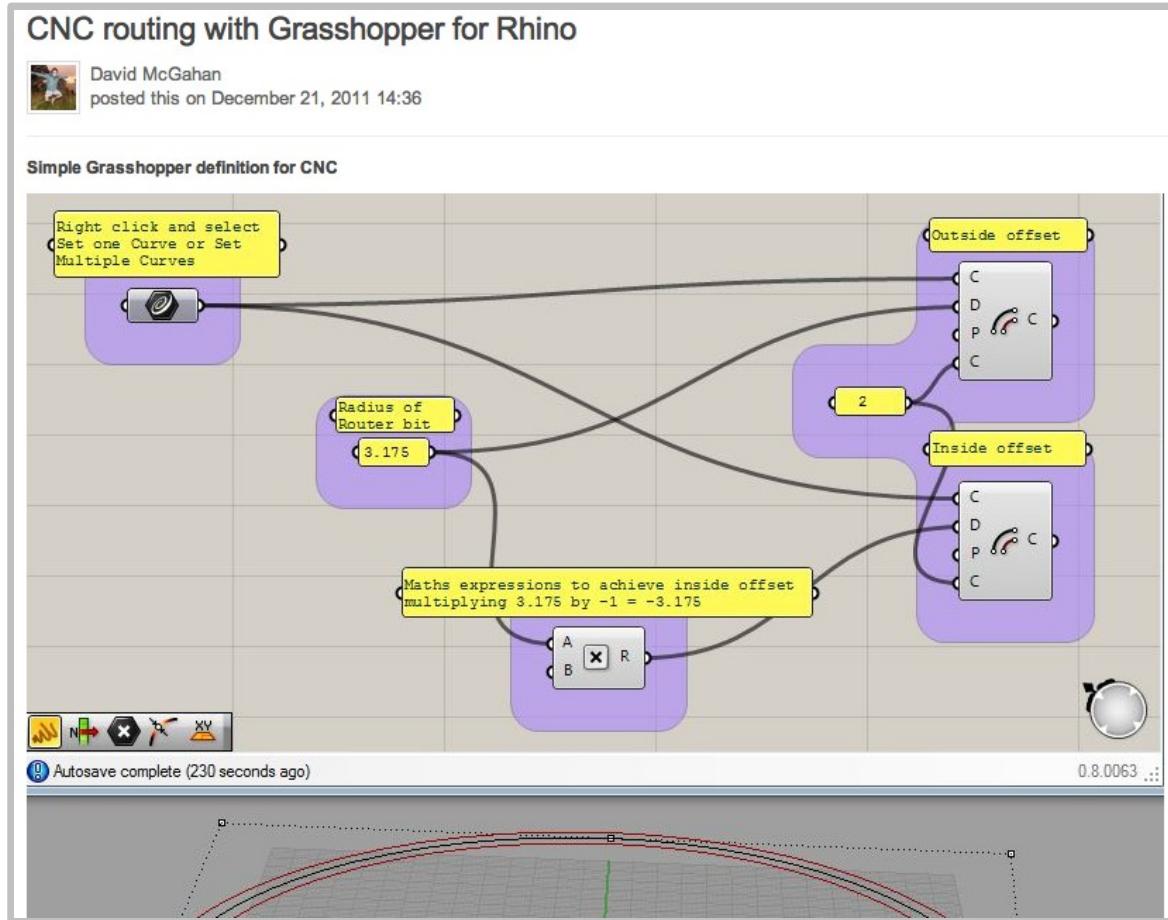
As the router cut out your design there can be small areas of waste can be left in the middle which are not beefy enough to support themselves. These usually break off leaving a rough edge and cause the machine to jam damaging it and your work. If you have a narrow/small strip of waste, it's best to add extra lines so the area is left clear. These extras cutting paths should be open paths so the router knows to cut them before the cutting lines for your design.



You cannot avoid the size of the tool this time, so your design has to be drafted according to that.

Source: <http://support.ponoko.com/entries/20735156-things-you-must-know-for-cnc-routing>

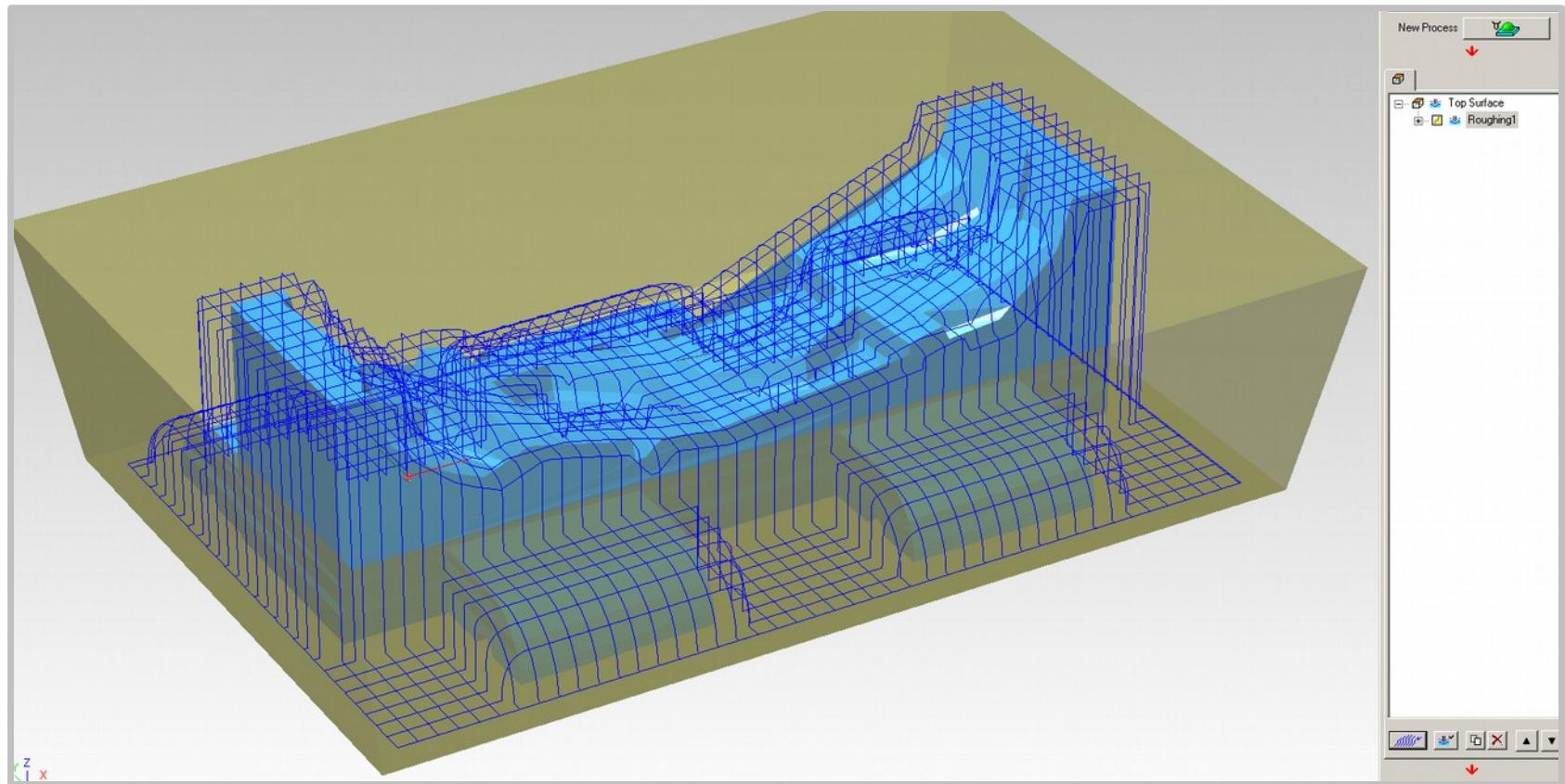
# CNC routing with Grasshopper for Rhino



The Grasshopper plugin for Rhino is also useful for much simpler tasks such as offsetting lines as you might do manually for CNC routing.

Source: <http://support.ponoko.com/entries/20786136-cnc-routing-with-grasshopper-for-rhino>

# Roland Modela Player 4



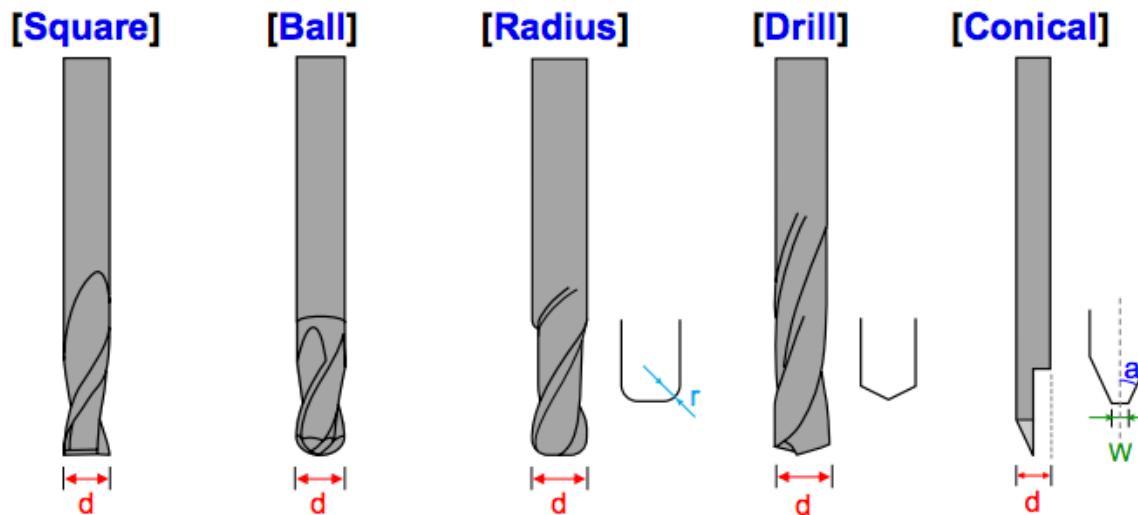
MODEL A Player is a CAM software that allows importing of 3D files for milling it. Virtual MODEL A provides a quick preview of the entire milling operation.

Source: [http://academy.cba.mit.edu/content/tutorials/General\\_Machine\\_Tutorials/Milling/ModelaPlayer4\\_tutorial\\_v2.html](http://academy.cba.mit.edu/content/tutorials/General_Machine_Tutorials/Milling/ModelaPlayer4_tutorial_v2.html)  
[http://www.intellecta.net/mdx-15\\_20.html](http://www.intellecta.net/mdx-15_20.html) [http://www.rolanddg.com/product/3d/3d/mdx-20\\_15/application.html](http://www.rolanddg.com/product/3d/3d/mdx-20_15/application.html)

# Roland Modela Player 4: adding milling bits

It is possible to register new tools. Roland original tools are originally registered.

Tool Type, Tool Material, Flute Diameter(**d**), Corner Radius(**r**), Blade Width(**w**) and Blade Angle(**a**) are necessary to be set to register a new tool.



MODELAPlayer is a CAM software that allows importing of 3D files for milling it. Virtual MODELAPlayer provides a quick preview of the entire milling operation.

Source: <http://www.elecprint.ch/downloads/modelaplayer4e.pdf>

# Many different milling bits ...



---

You may encounter also bigger and very different milling bits...

# Many different milling bits: square bits



You may encounter also bigger and very different milling bits...

# Many different milling bits: round bits



You may encounter also bigger and very different milling bits...

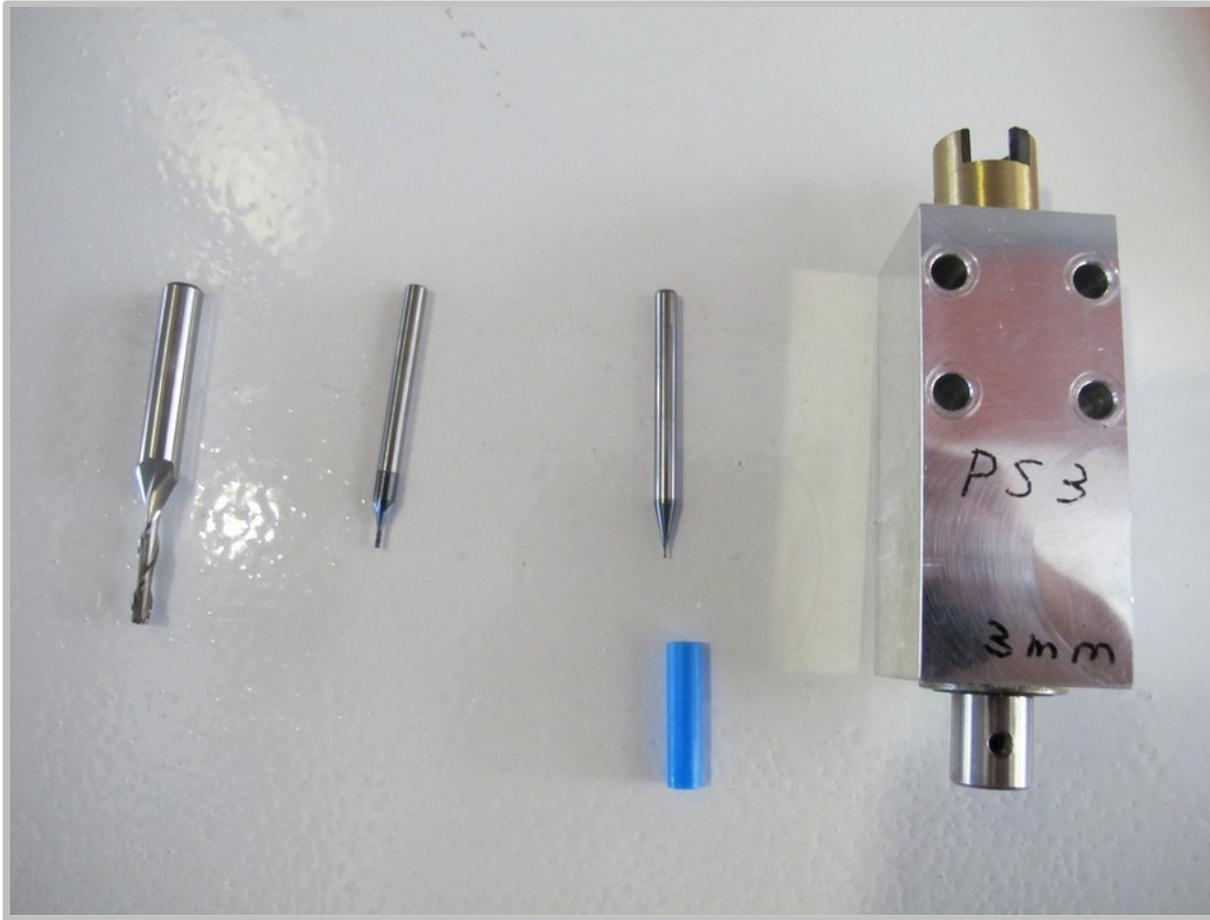
# Our milling bits



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Diameters = 3 mm, 1/32 inch (0.79375 mm), 1/64 inch (0.396875 mm).

# Our milling bits

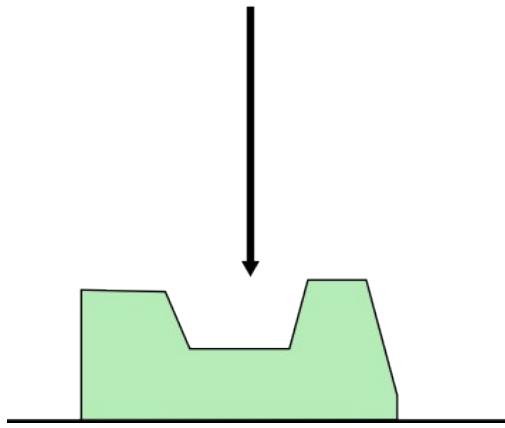


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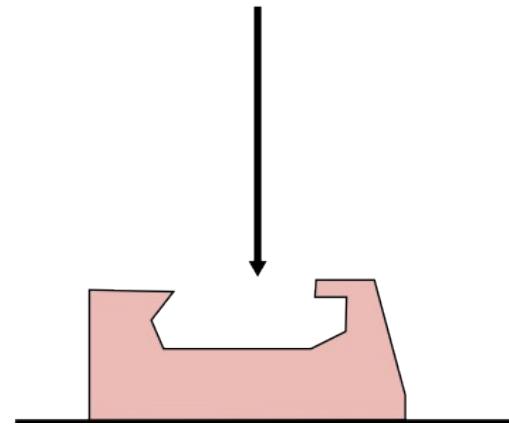
Diameters = 3 mm, 1/32 inch (0.79375 mm), 1/64 inch (0.396875 mm).

# Limitations for the geometry

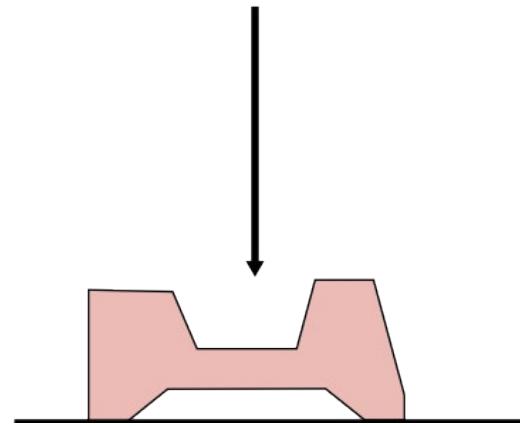
This geometry works well.



This geometry has undercuts.



This geometry has features on the back side.



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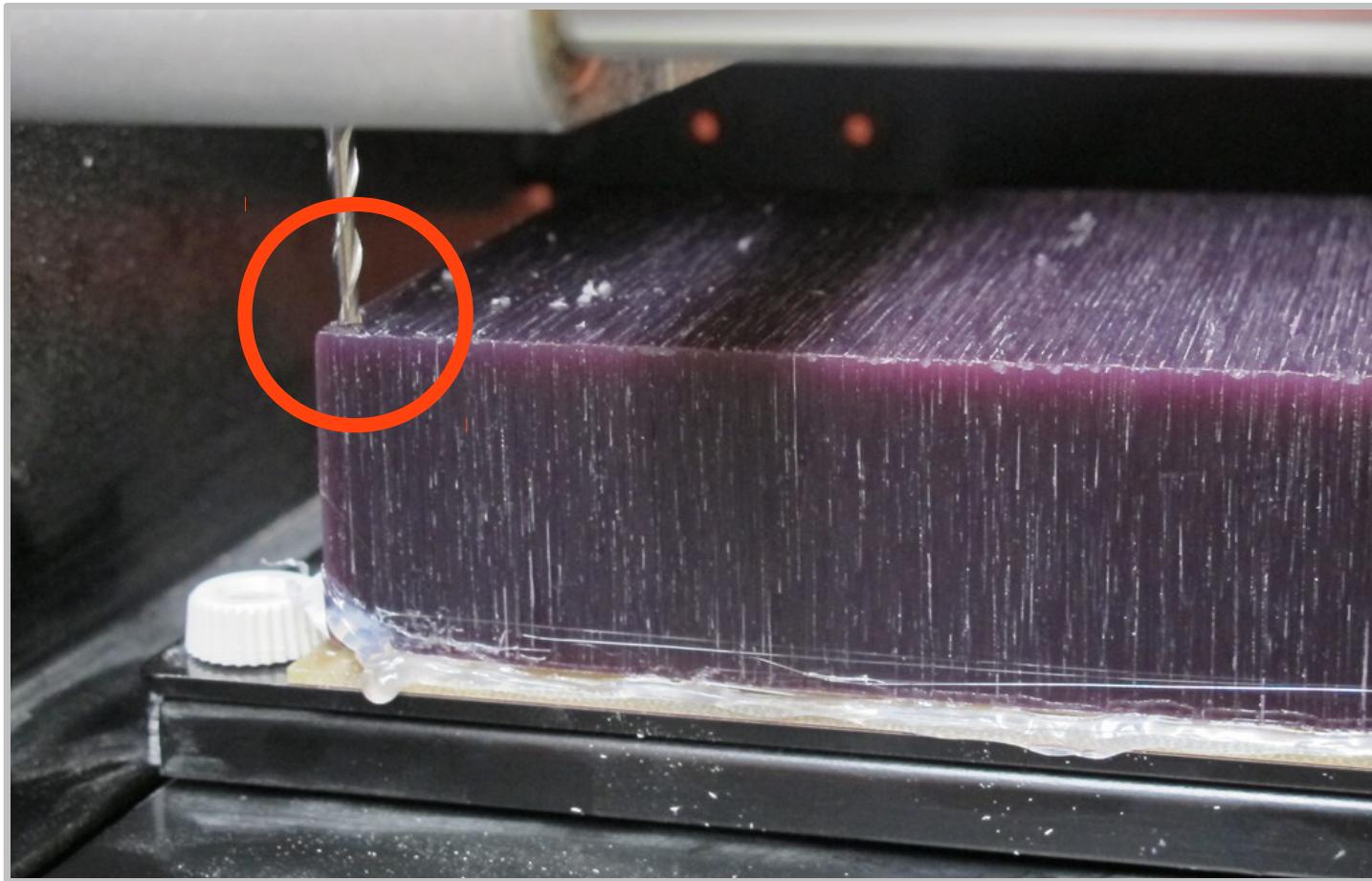
No undercuts and features on the back side can be milled on a 3-axis CNC milling machine.

# Limitations for the geometry



Diameters = 3 mm, 1/32 inch (0.79375 mm), 1/64 inch (0.396875 mm).

# Always, set the Zero: X, Y, Z

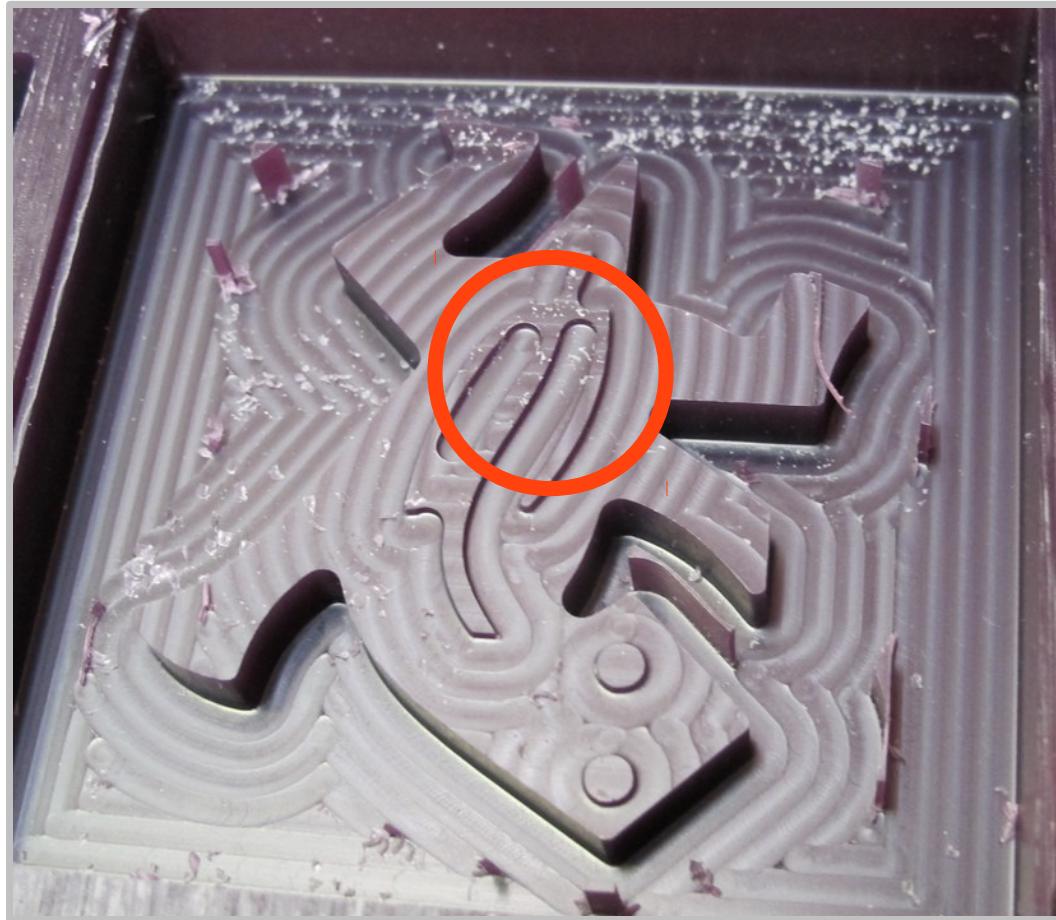


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And write down the X and Y coordinates! Furthermore, don't mill around it, so you can preserve it for future passes.

Source: <http://www.flickr.com/photos/aaltofablab/6924563776/in/photostream>

# When designing, think about the milling bit

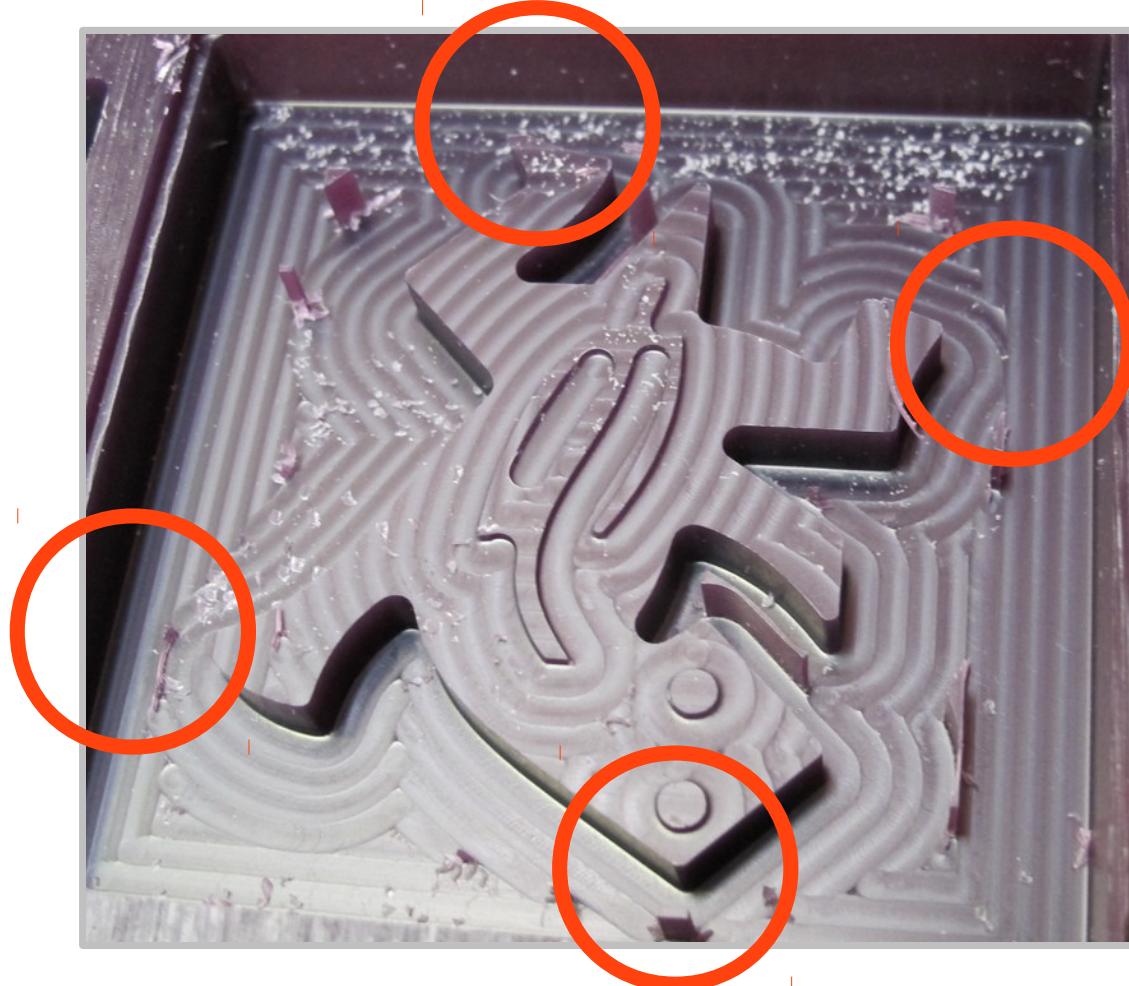


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Leave enough space for the milling bit to pass, or it will erase part of your details. Rough finish should leave a 1.4 mm offset.

Source: <http://www.flickr.com/photos/aaltofablab/7070645517/in/photostream>

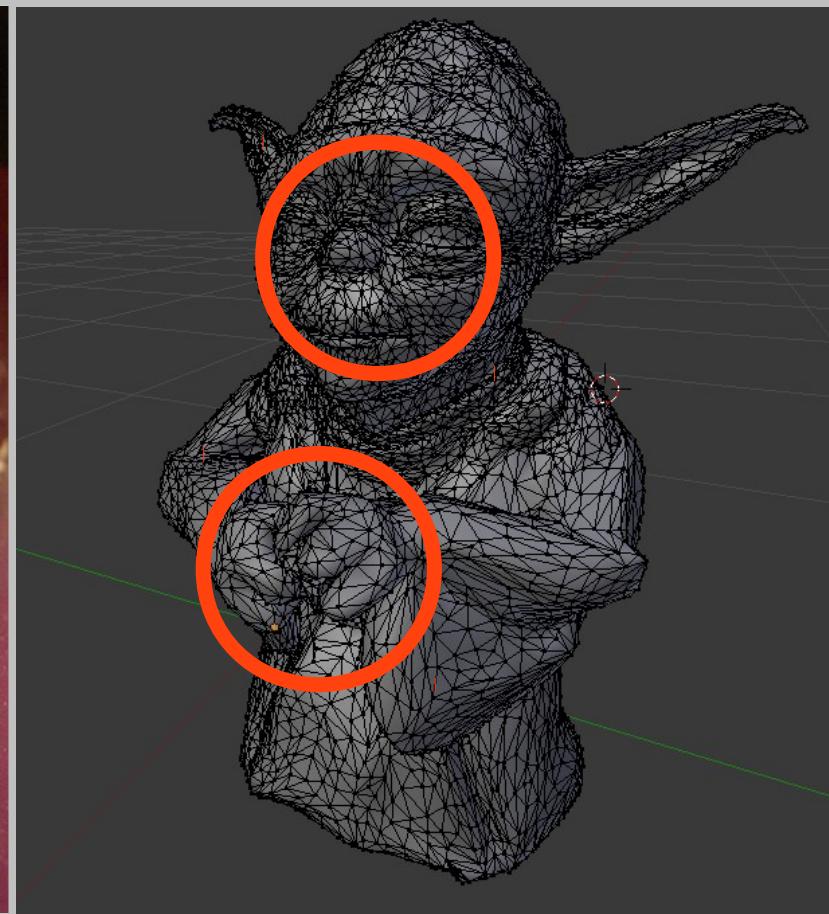
# When designing, think about the milling bit



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Leave enough space **also** around your object!

# When designing, think about the milling bit

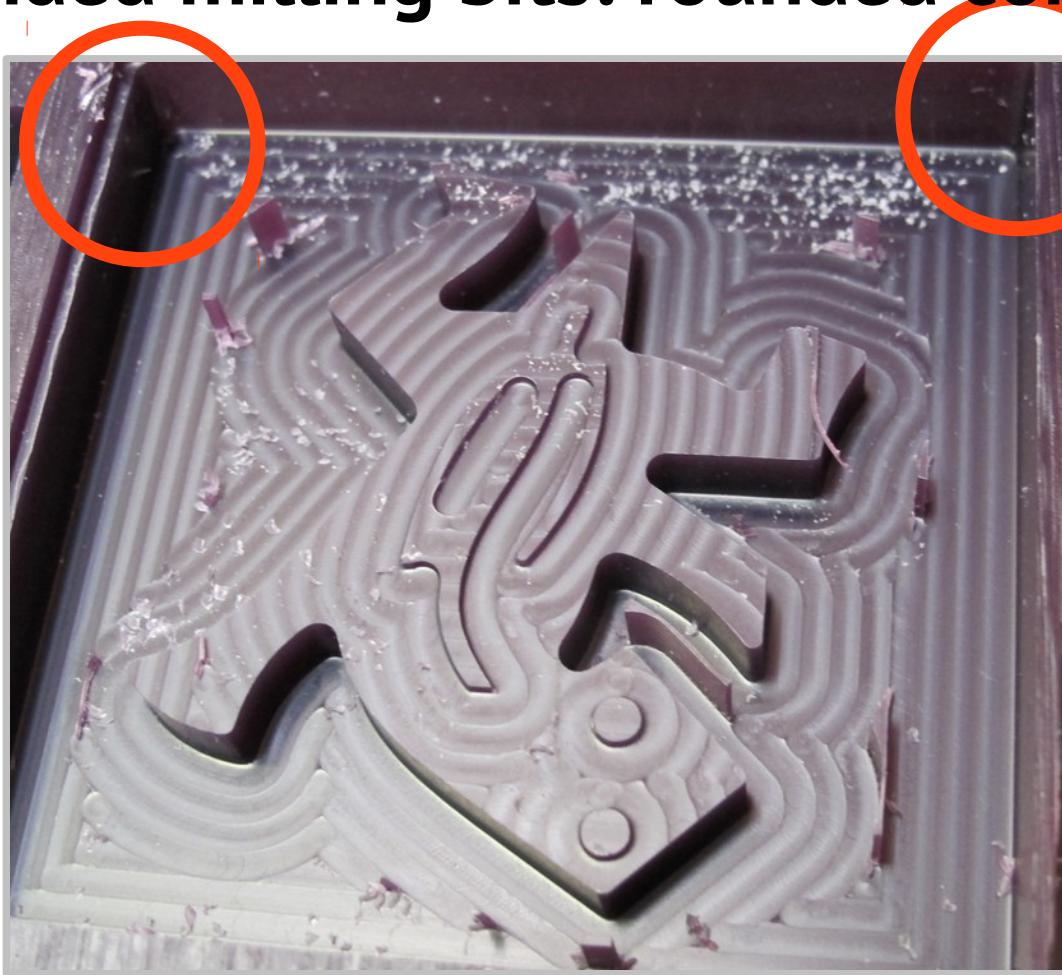


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Your tiniest detail will be the size of your smallest milling bit, not the resolution of your mesh, think about it!

Source: [http://www.flickr.com/photos/massimo\\_menichinelli/6765894657/in/photostream](http://www.flickr.com/photos/massimo_menichinelli/6765894657/in/photostream)

# Rounded milling bits: rounded corners

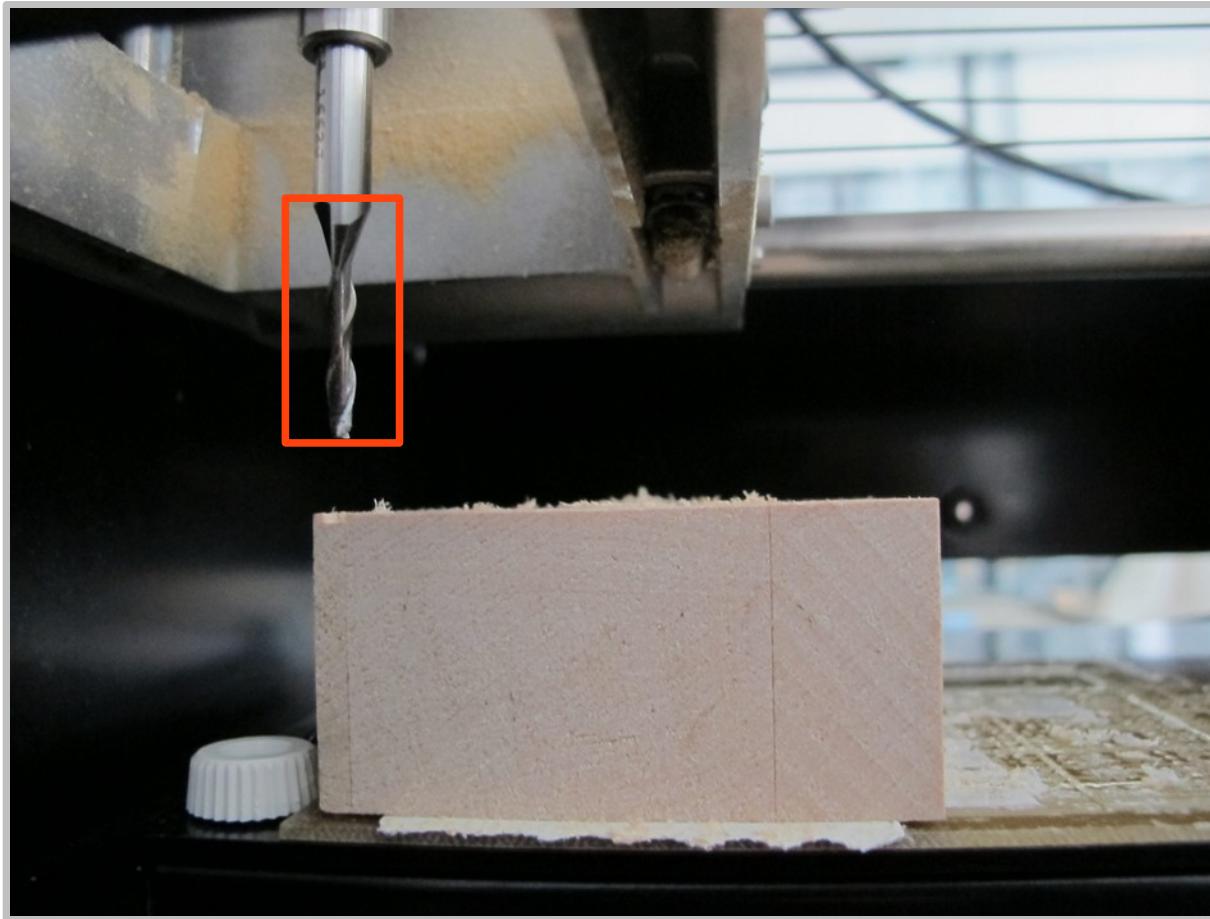


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The milling bit is rounded and rotates, so your corners will be rounded, and the radius is the same of your biggest milling bit.

Source: <http://www.flickr.com/photos/aaltofablab/7070645517/in/photostream>

# The milling bits also determines the depth

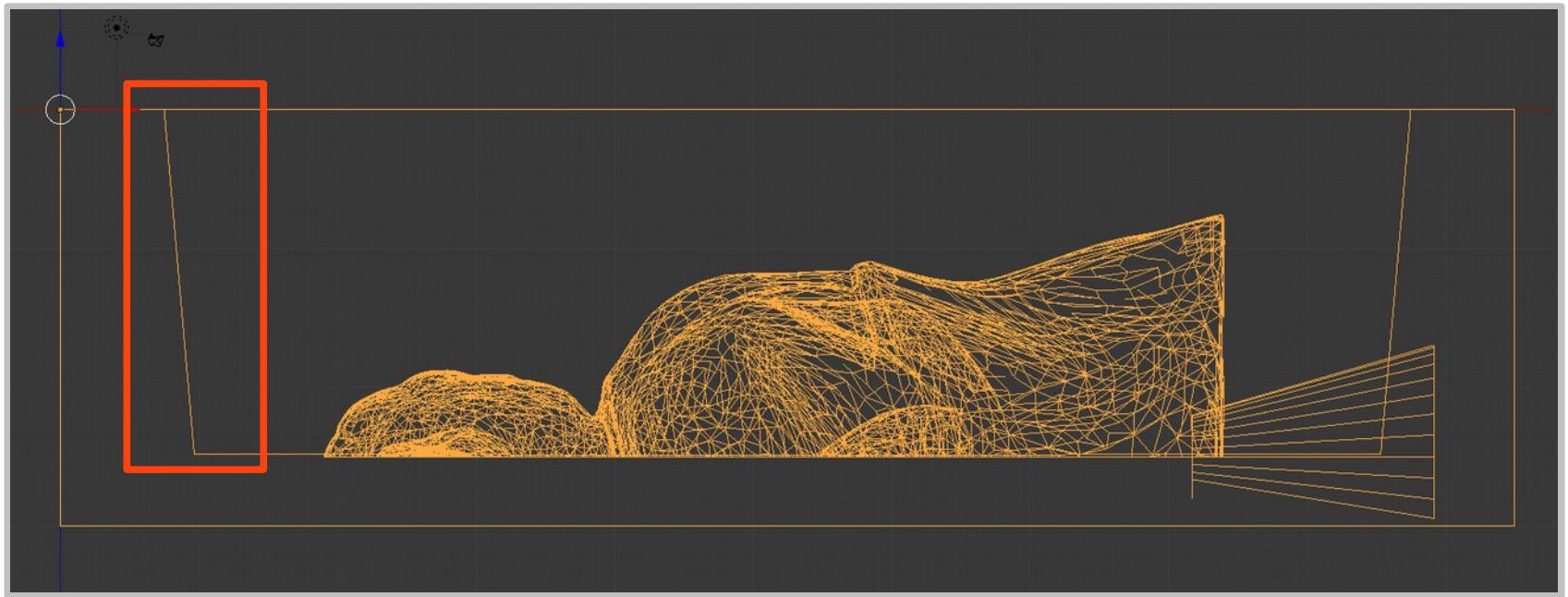


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Even if your modelling block is higher than the milling bit, it is the last one that determines how deep you can mill.

Source: <http://www.flickr.com/photos/aaltofablab/7194259202/in/photostream>

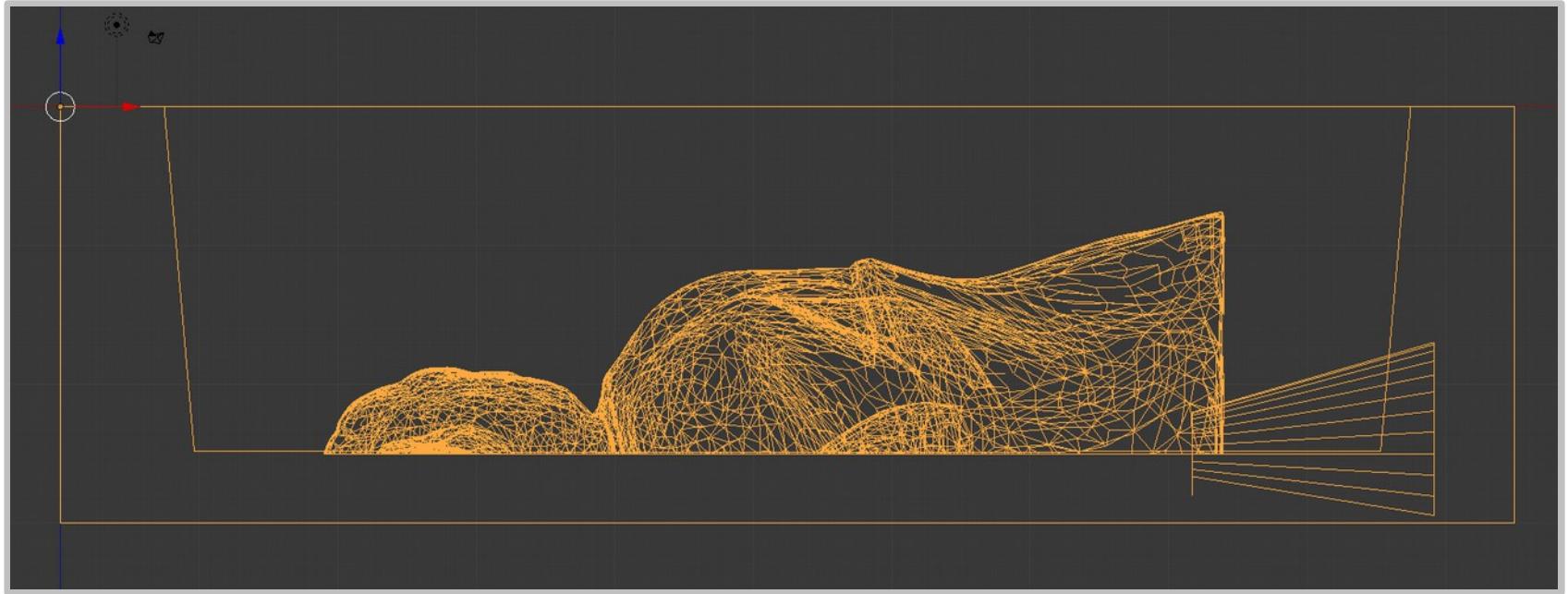
# Depth: draft angles can help



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Draft angles can help in reaching deeper with your milling bit.

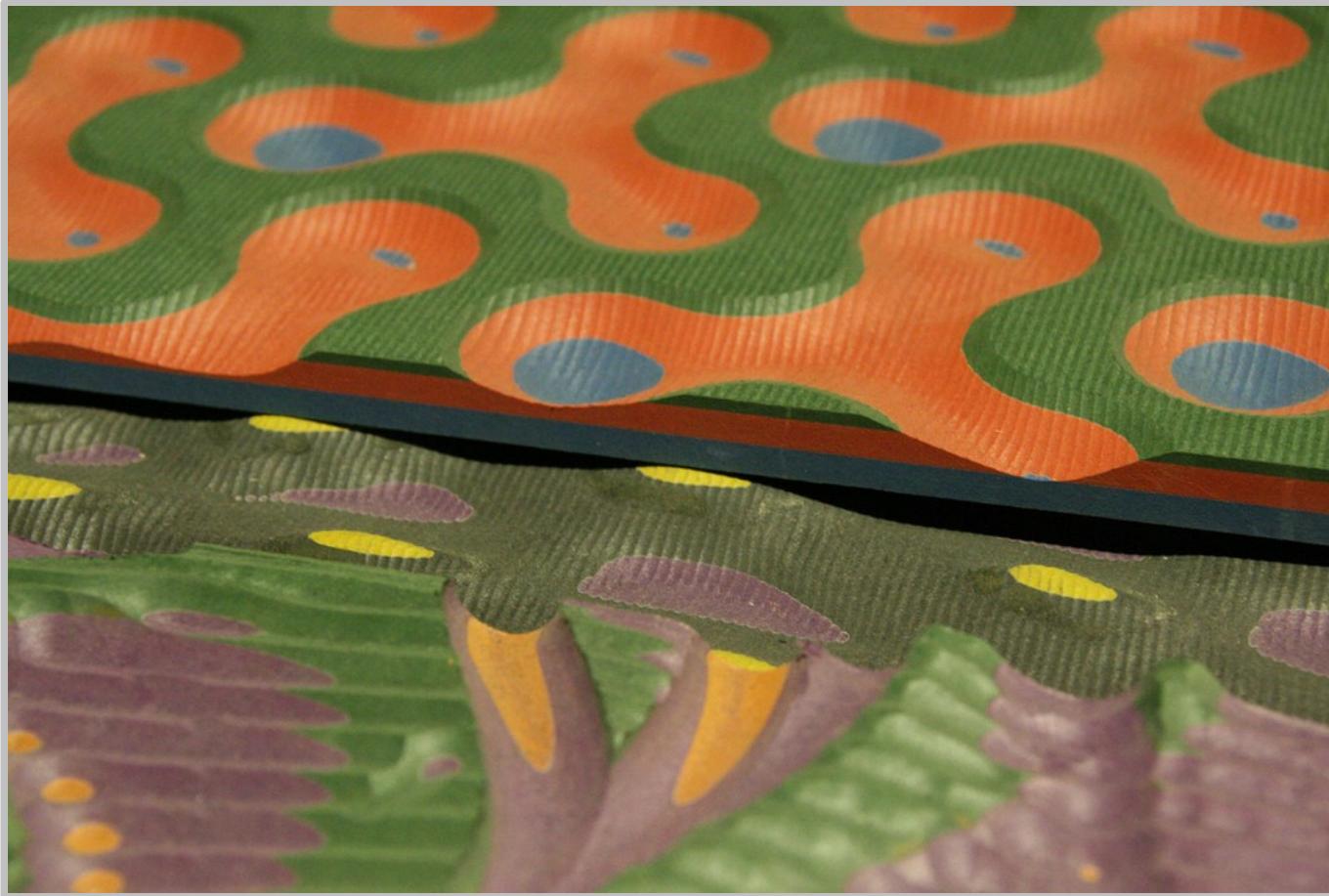
# Depth: draft angles can help



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Draft angles can help in reaching deeper with your milling bit.

# Depth: the layers of the material



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If your material has many different layers, you can play with its structure to achieve different effects.

Source: [http://www.flickr.com/photos/massimo\\_menichinelli/6680470207/in/photostream](http://www.flickr.com/photos/massimo_menichinelli/6680470207/in/photostream)

# Depth: the layers of the material

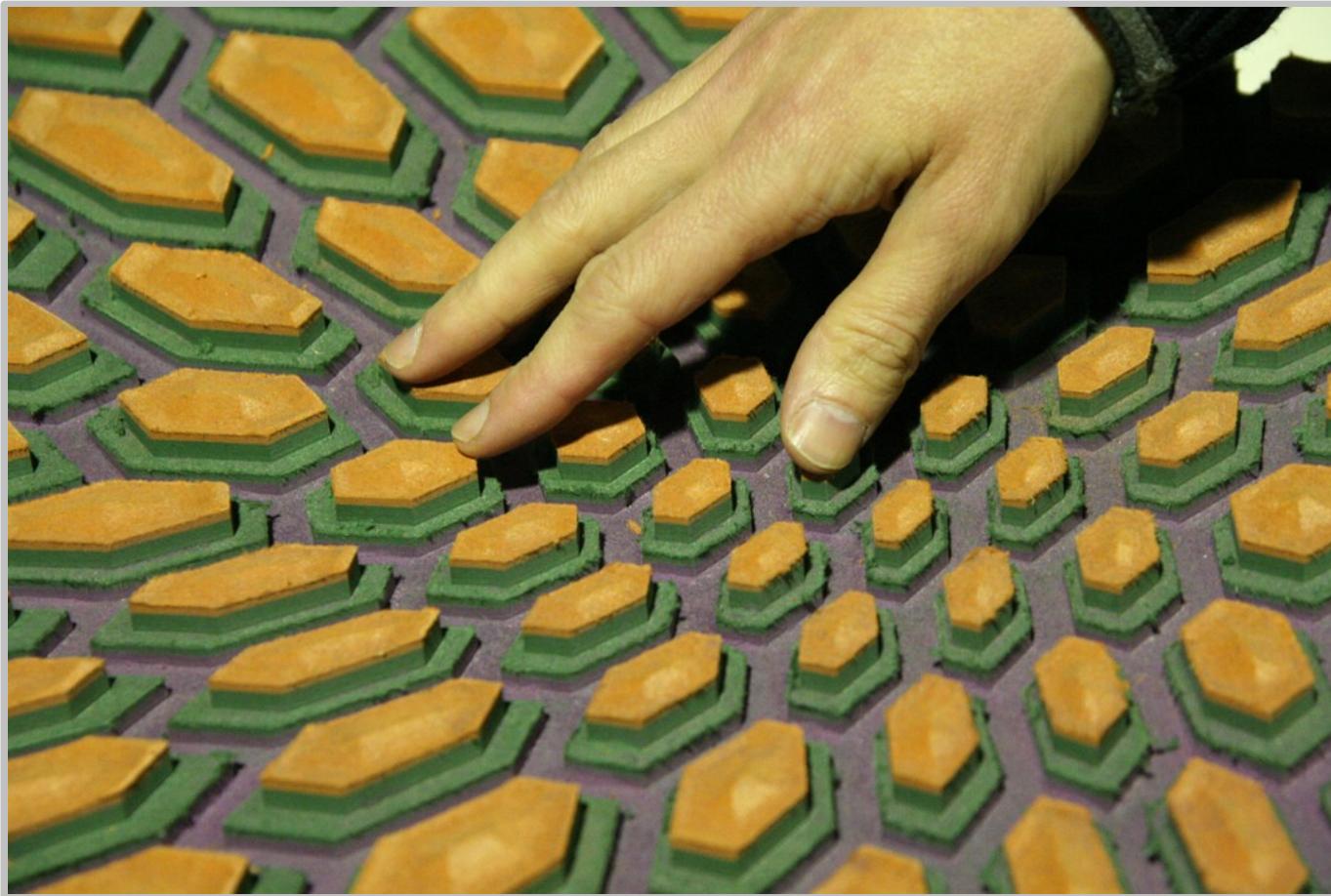


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If your material has many different layers, you can play with its structure to achieve different effects.

Source: [http://www.flickr.com/photos/massimo\\_menichinelli/6680488643/in/photostream/](http://www.flickr.com/photos/massimo_menichinelli/6680488643/in/photostream/)

# Depth: the layers of the material



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If your material has many different layers, you can play with its structure to achieve different effects.

Source: [http://www.flickr.com/photos/massimo\\_menichinelli/6680483663/in/photostream](http://www.flickr.com/photos/massimo_menichinelli/6680483663/in/photostream)

# Layers: Ripples, by Toyo Ito



Ripples, winner of the 2004 Compasso d'Oro, is made of a laminated composite of five different solid woods.

Source: [http://www.horm.it/eng/prodotti\\_di\\_design/toyo-ito/collezione-toyo-ito-foto.php?id=99](http://www.horm.it/eng/prodotti_di_design/toyo-ito/collezione-toyo-ito-foto.php?id=99)  
[http://www.bonluxat.com/a/Toyo\\_Ito\\_Ripples\\_Bench.html](http://www.bonluxat.com/a/Toyo_Ito_Ripples_Bench.html)

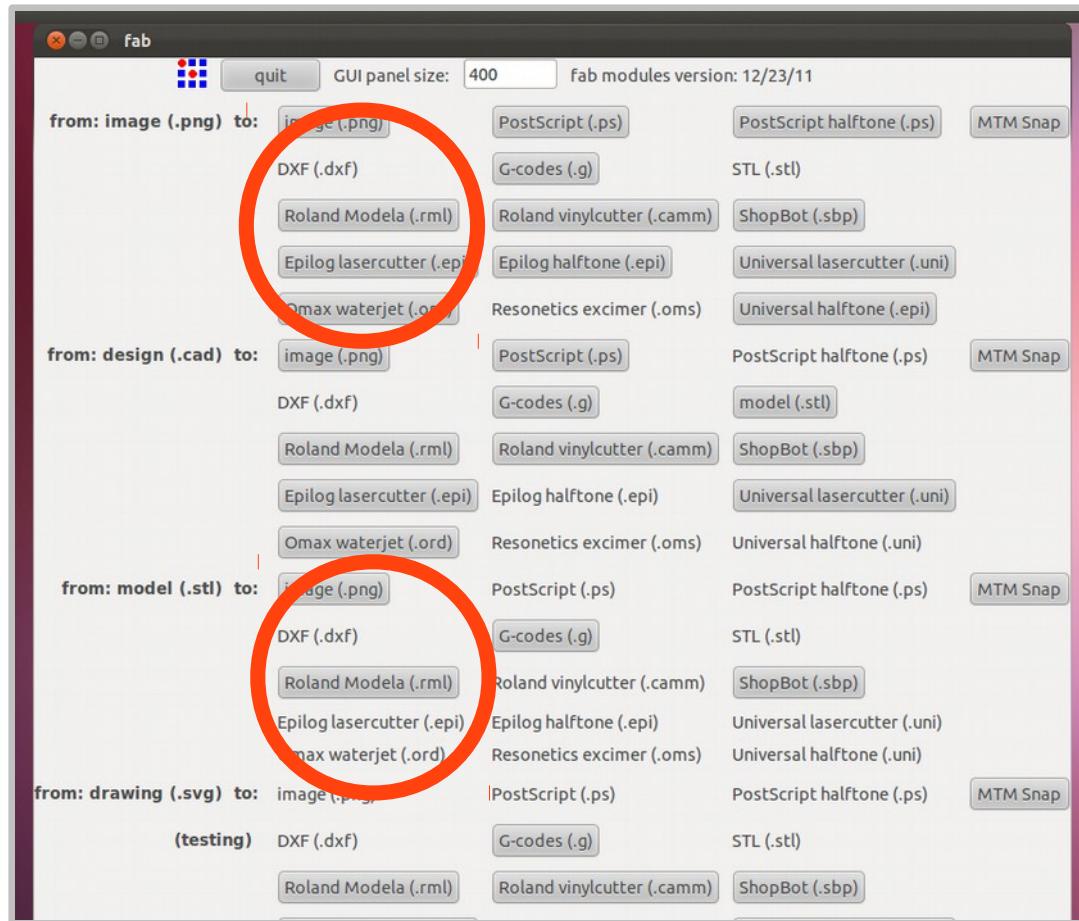
# Layers: Ripples, by Toyo Ito



The whole manufacturing process of the table, it is worth watching not only for the CNC part but also for understanding the complexity behind the object.

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

# Fab Modules: the FabLab standard software



A software package to run all the FabLab machines on Linux and Mac (if you manage to install it ;-)).

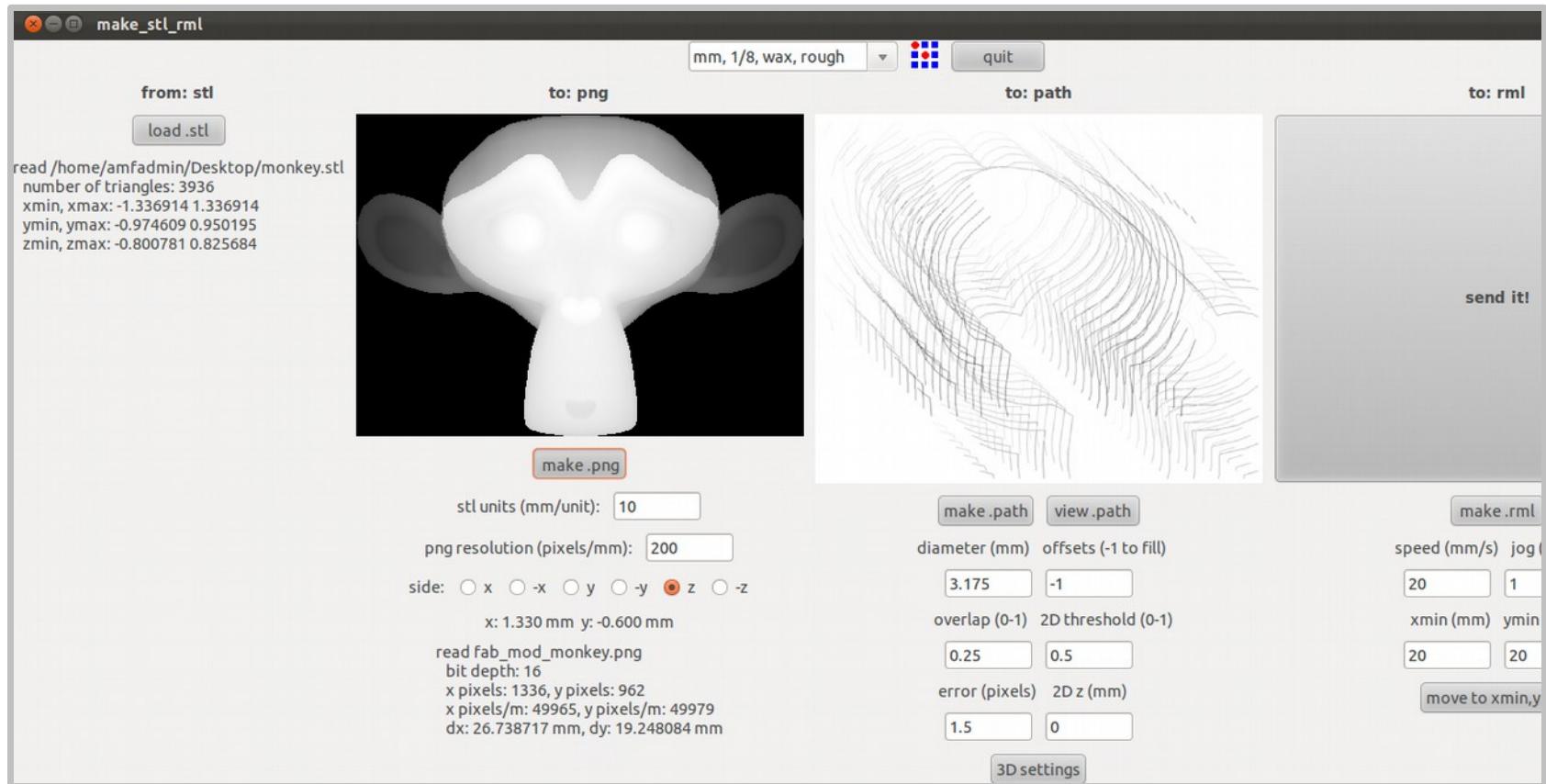
Source: <http://kokompe.cba.mit.edu/dist/index.html>

# Fab Modules: milling a 2D PCB



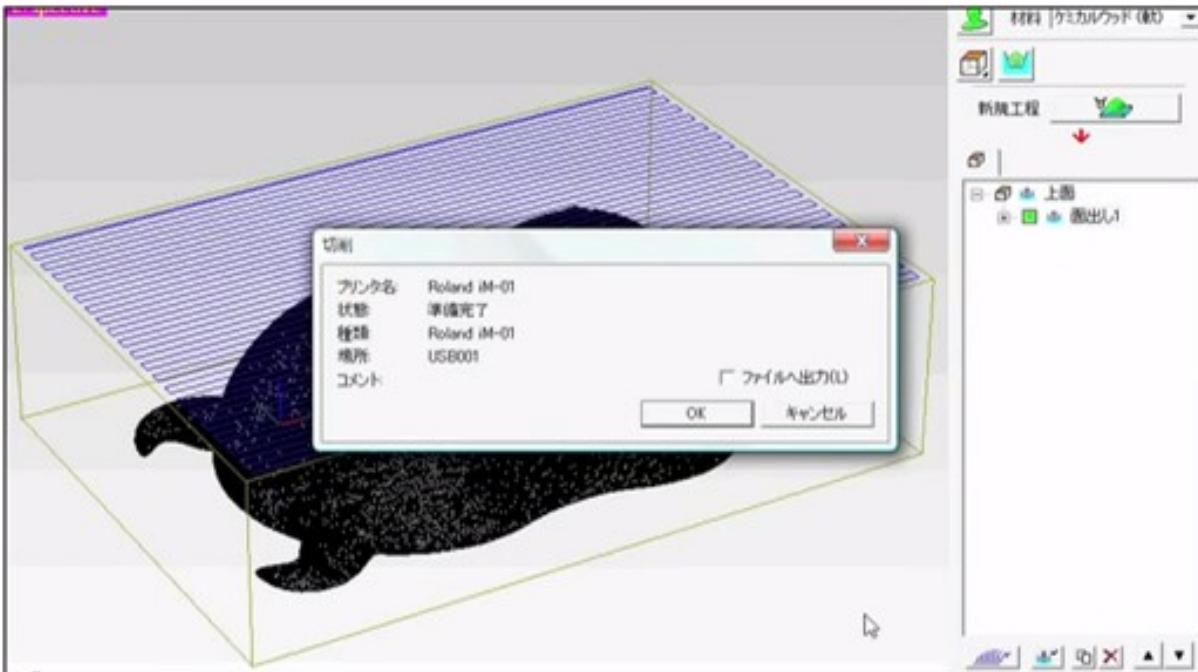
The white part will be milled away: the software generate the paths (each milling bit have its own function and path structure).

# Fab Modules: milling a 3D object



The software will translate the 3D model into a BW gradient: white is the top, black the bottom (and then you can set the whole height).

# Roland Modela Player 4: process



to start cutting.

A tutorial for iModela, but the process is the same for the MDX-200 as the software is the same.

Source: <http://youtu.be/ijHoaG6Y5E>

# Roland Modela Player 4: finishing



If you have only 3 axis, splitting the model into two halves can be a good technique for achieving complex shapes.

Source: [http://youtu.be/DVfJIU\\_wD0c](http://youtu.be/DVfJIU_wD0c)

# Rough cut and Finish cut



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Two passes: first the rough cut, then the finish cut.



Aalto University  
Media Factory

# Thank you!!

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

