Making it Real

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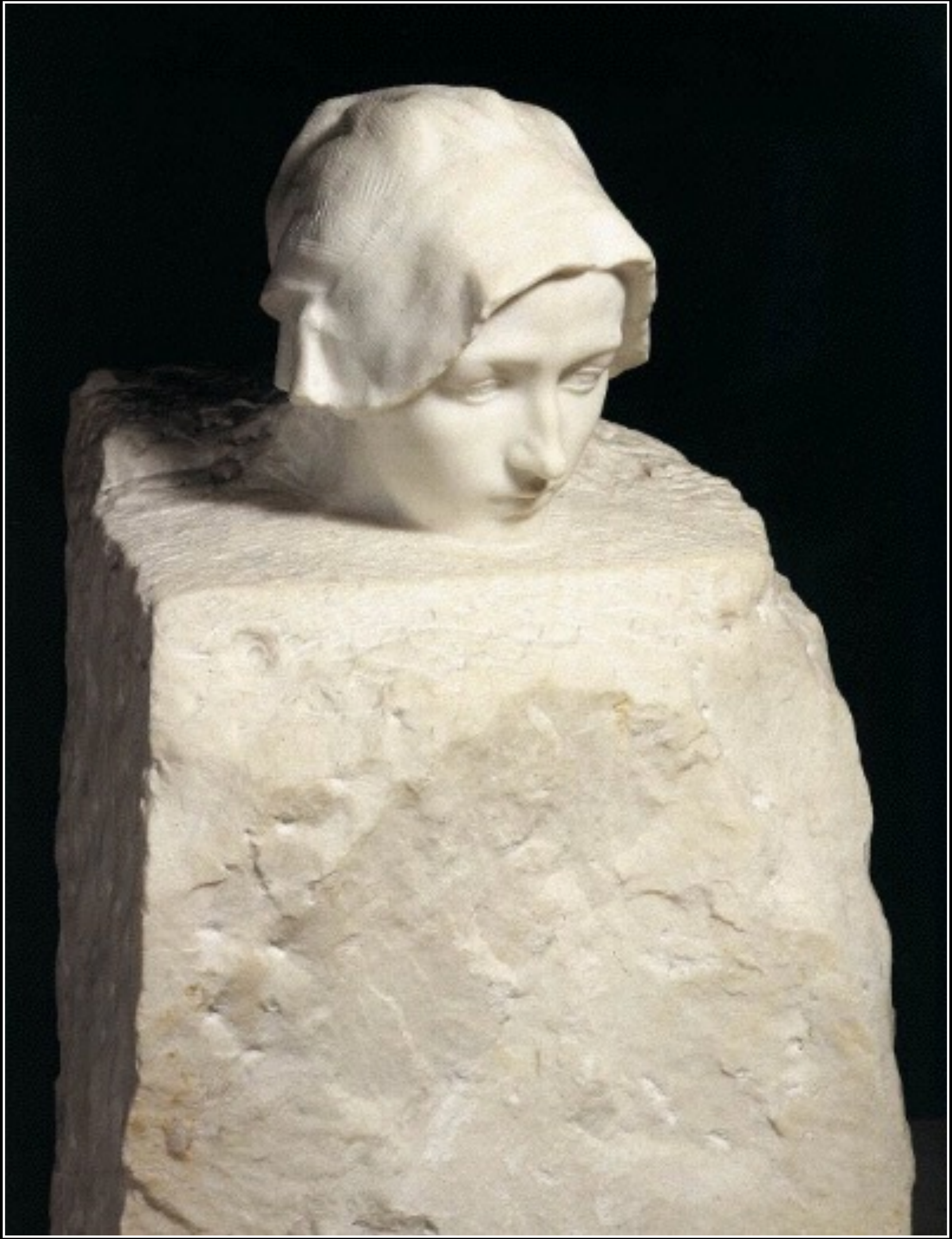
- Software challenge



Auguste Rodin when asked "How do create a sculpture of a beautiful woman?"
He replied, "Easy. Start with a big block of marble and chip away anything that doesn't look like a woman."

Slides will be available here:
http://paulbourke.net/csiro2016/

Introduction

- The basic idea behind most visualisation displays is to fully engage the human visual system.

- Leveraging the capabilities:
  - depth perception through stereopsis (stereoscopic displays)
  - immersion through peripheral vision (CAVEs, domes, cylinders, HMDs)
  - fidelity (resolution, scale, dynamic range)

- Sonification is well established as a means of also conveying information to our brain.

- Haptic provide force feedback through sense of touch.

- Various sensors can also convey roughness, temperature, sensation of touch.

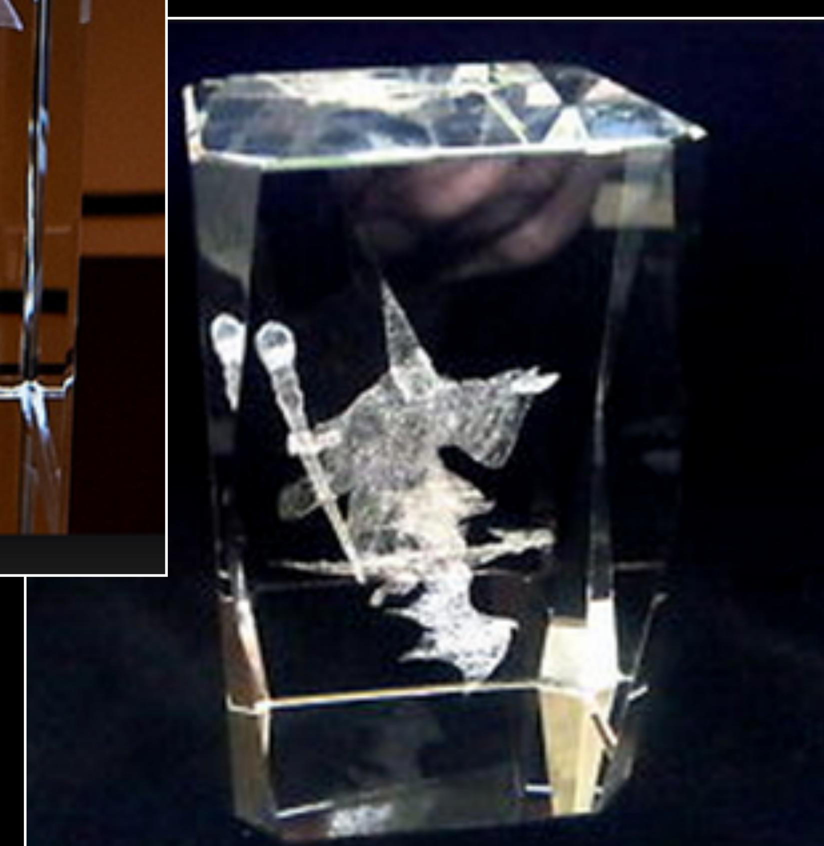
- Some work being one in using the sense of smell, still problematic from perspective of both capture and delivery, not to mention dynamic range and fidelity.

Motivation

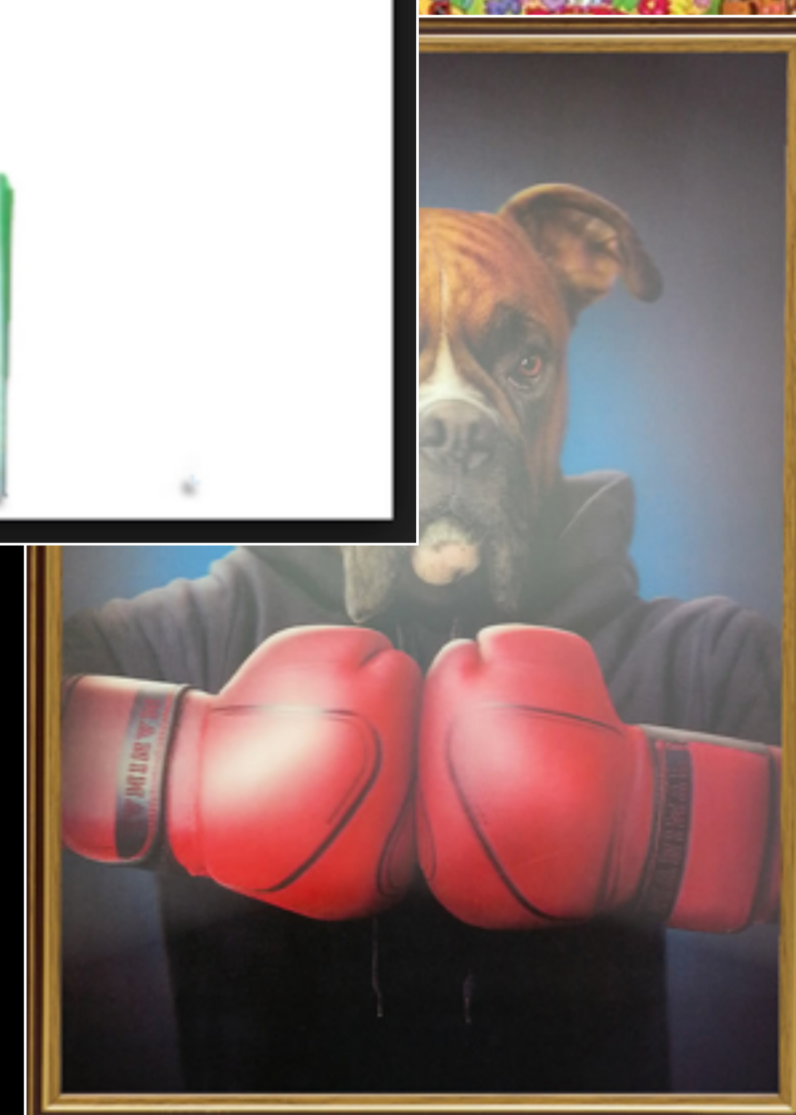
- Can data be effectively presented through physical models?
- Can new insight be enhanced (better or faster) through the use of physical models.
- Proposal: there are benefits of using our combined senses of touch and vision for data exploration.
- This is how we are designed to explore objects in real life!
- Personal additional interest has been the evaluation of technologies for visualisation that were intended for other applications, often frivolous ones.

3D printing

Crystal engraving



Lenticular prints

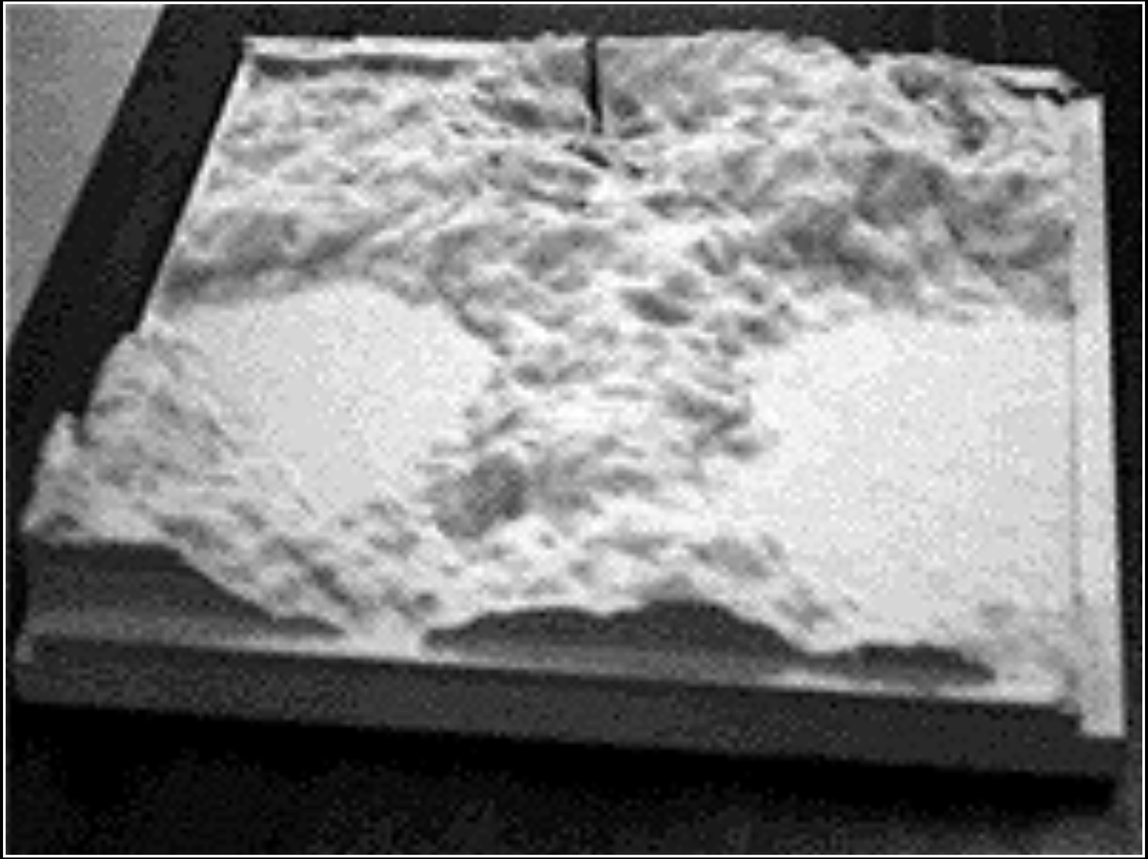


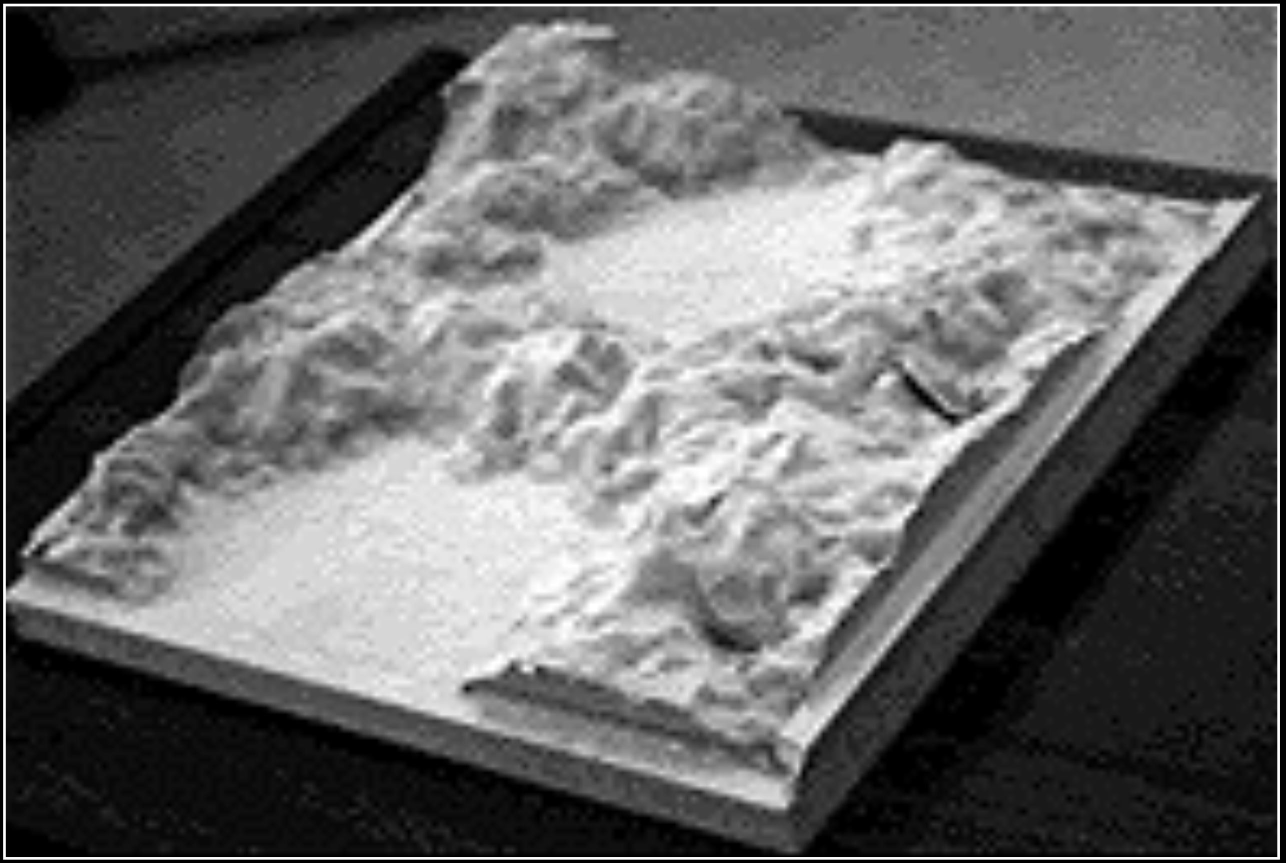
History - milling machine

- Employed at Auckland School of Architecture, Property and Planning circa 1986.
- Students regularly made layered contour models for landscape architecture.
- Cut from many contour layers of styrofoam, cardboard or wood (sound familiar?).

History - milling machine

- Engineering modified the machine so it could swap drill bits.
- I developed the software to control the drill bit, what cut away?
- A subtractive process compared to largely additive processes today.

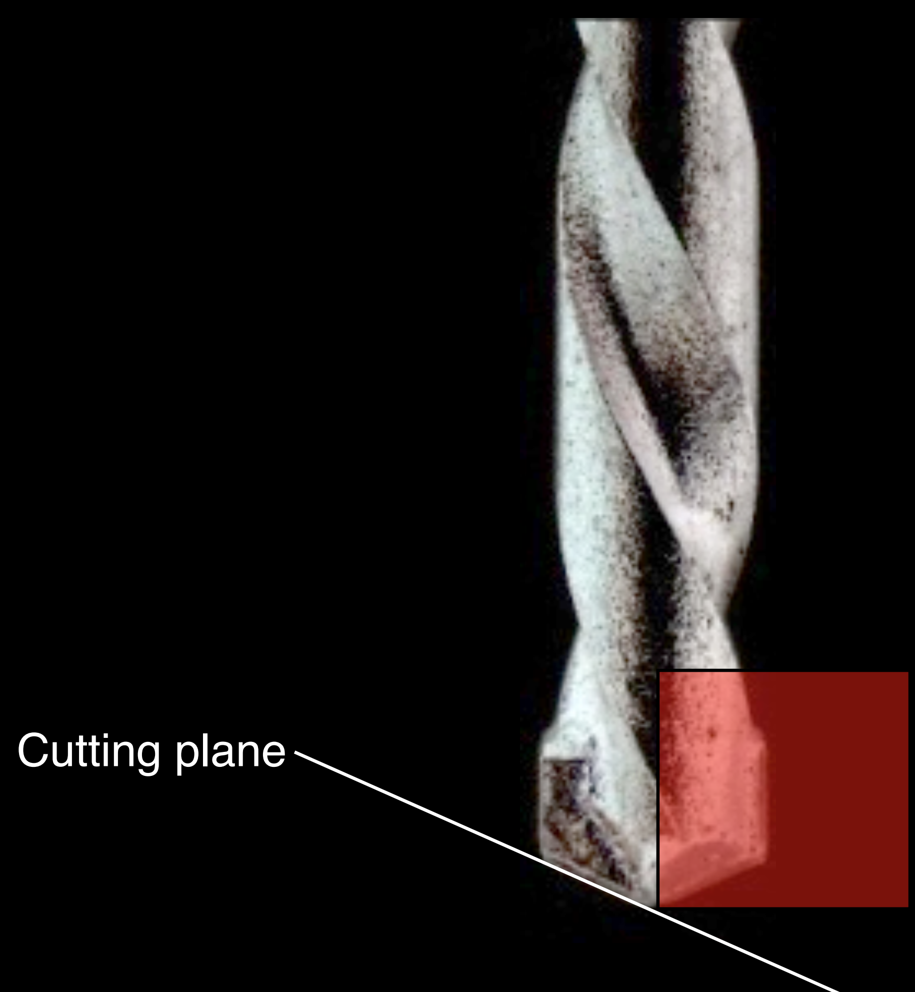


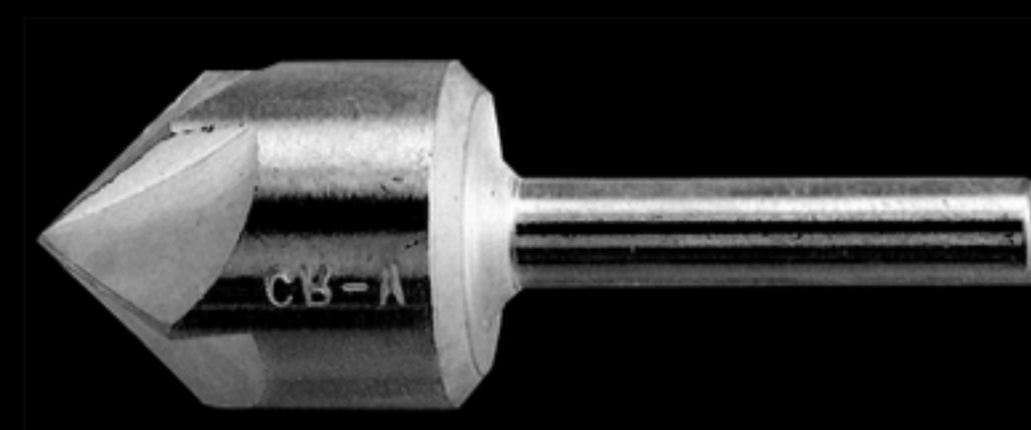


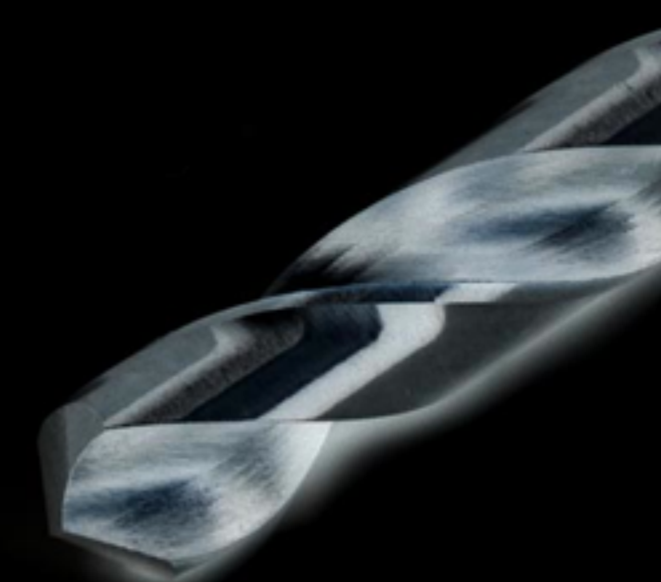
[Sorry for the poor quality images]

History - milling machine

- The cutting edge is not the top of the drill but the edge.
- Cannot simply use a drill bit that is related to the size of the finest structure, need to progressively reduce drill size or ….
  1. The process would take a very long time.
  2. When cutting some materials, like steel, it would be expensive on drill bits.

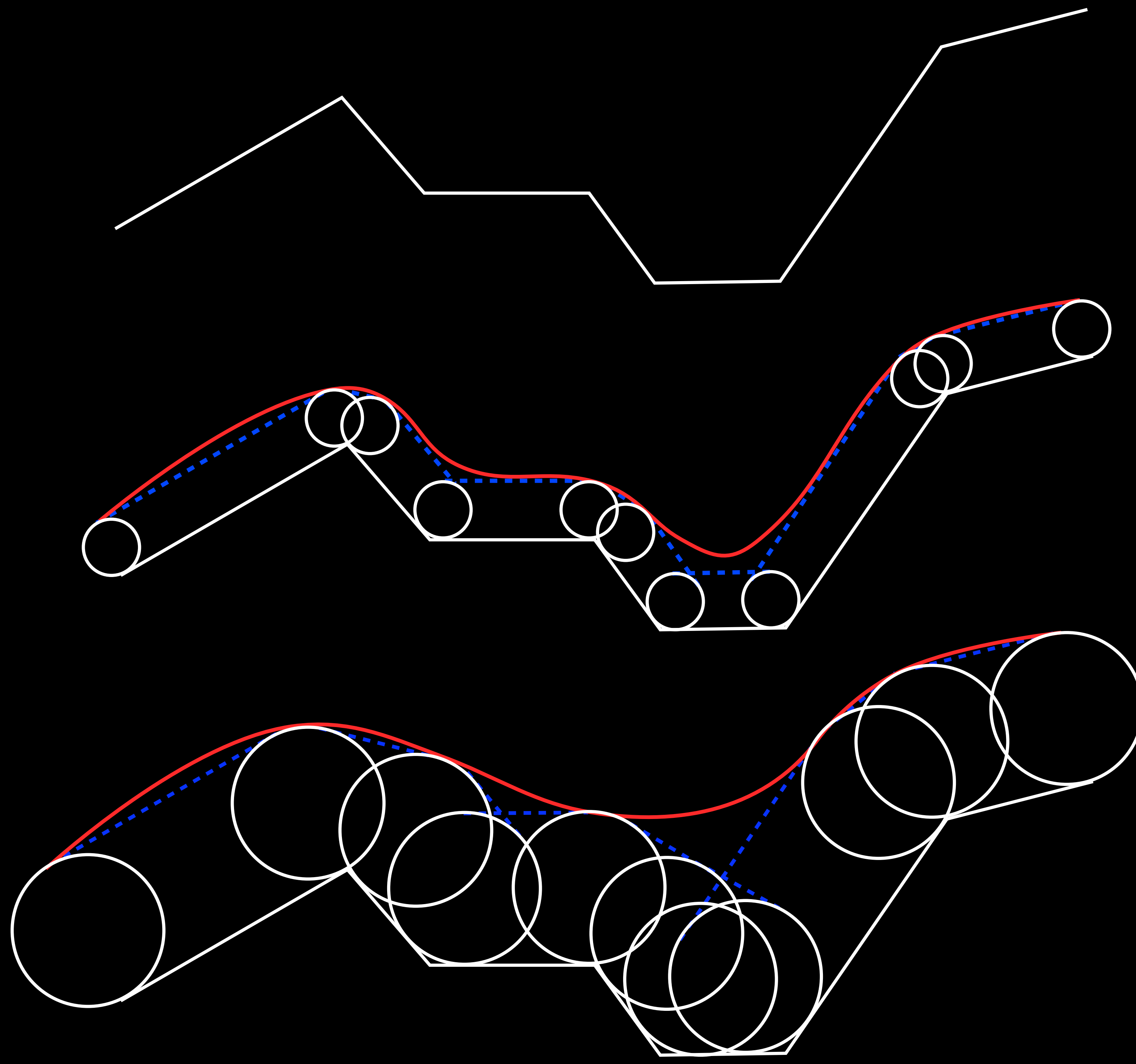






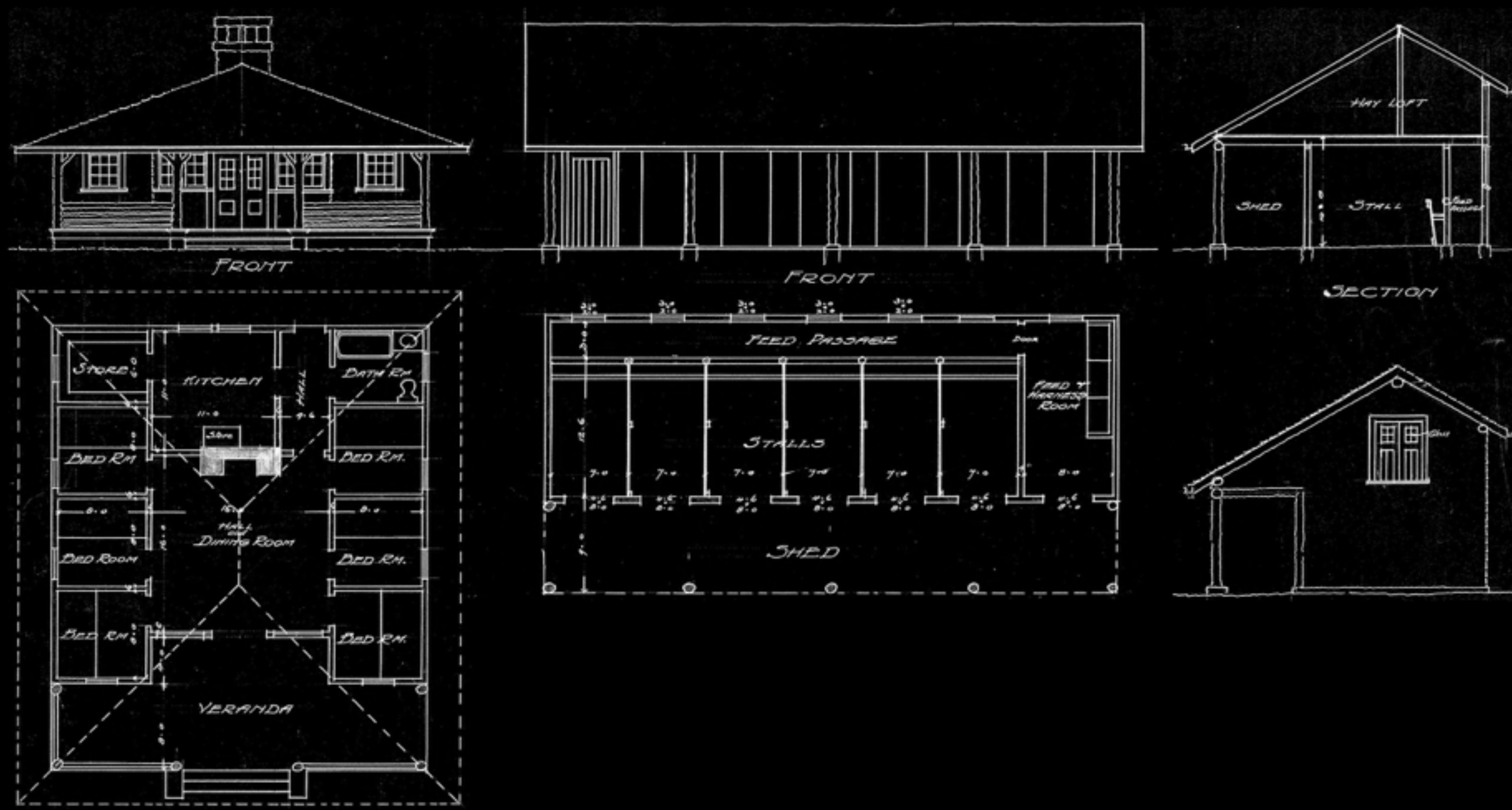
History - Rolling ball algorithm

- Produce increasingly smoother surfaces from desired detailed surface.



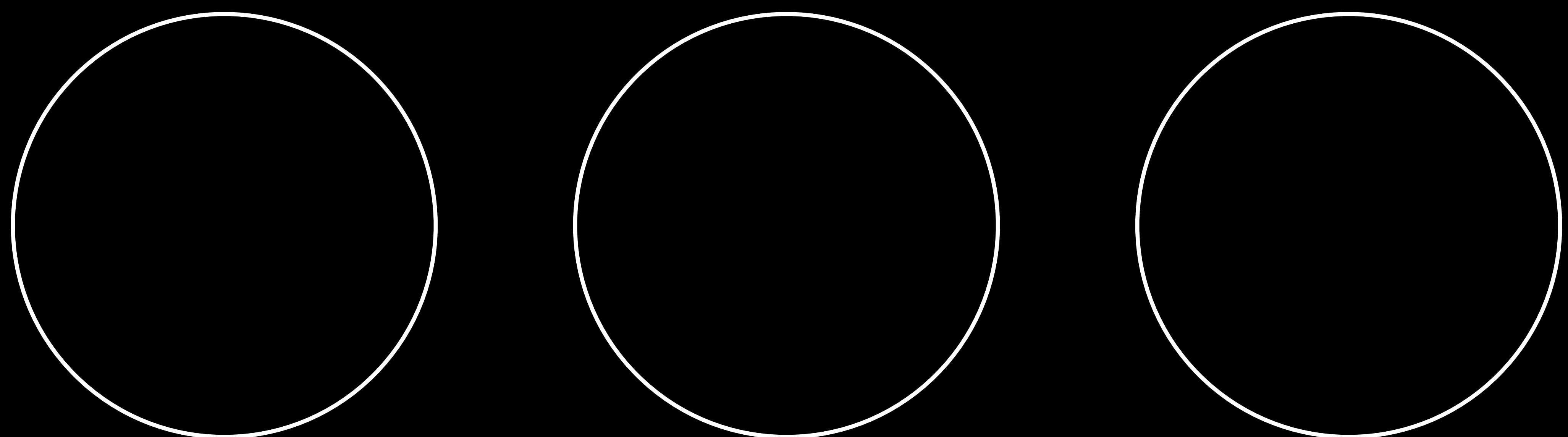
History - lathes

- Still at the School of Architecture, Property and Planning.
- Students tended to think plans and two elevations uniquely defined a geometry.



History - lathes

- What object is a circle in plan, front and side views?



Plan (x-y plane projection)

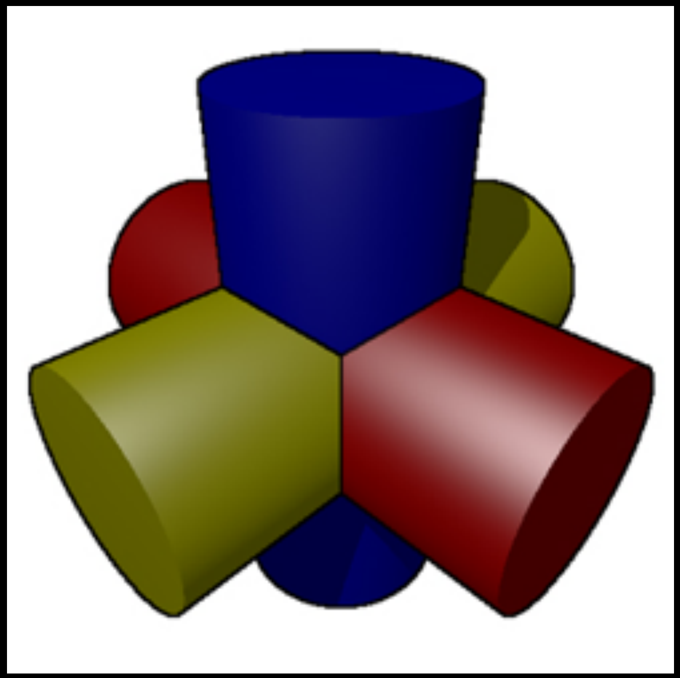
Elevation 1 (y-z plane projection)

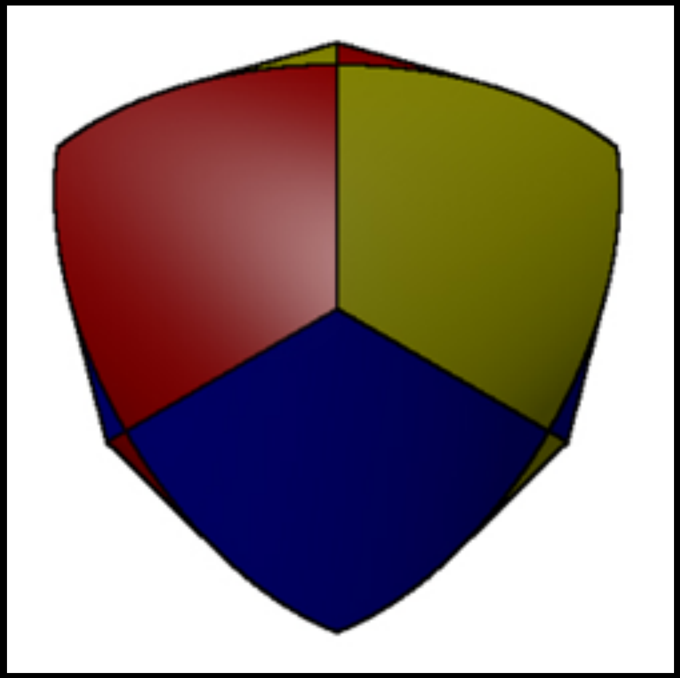
Elevation 2 (x-z plane projection)

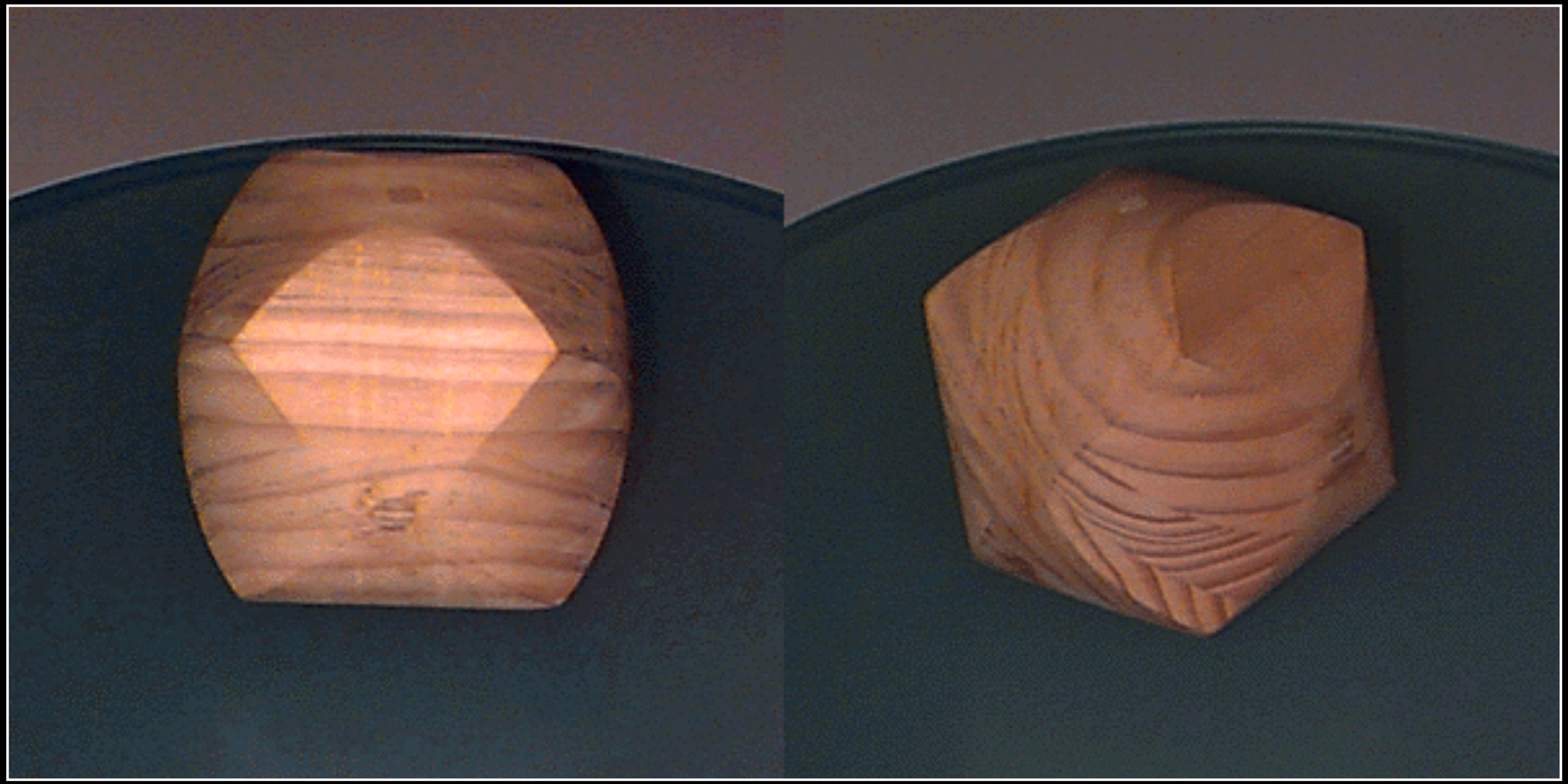
Besides a sphere!

History - lathes

- The intersecting volume of three orthogonal cylinders of equal radius.
- Has a name, Steinmetz solid.

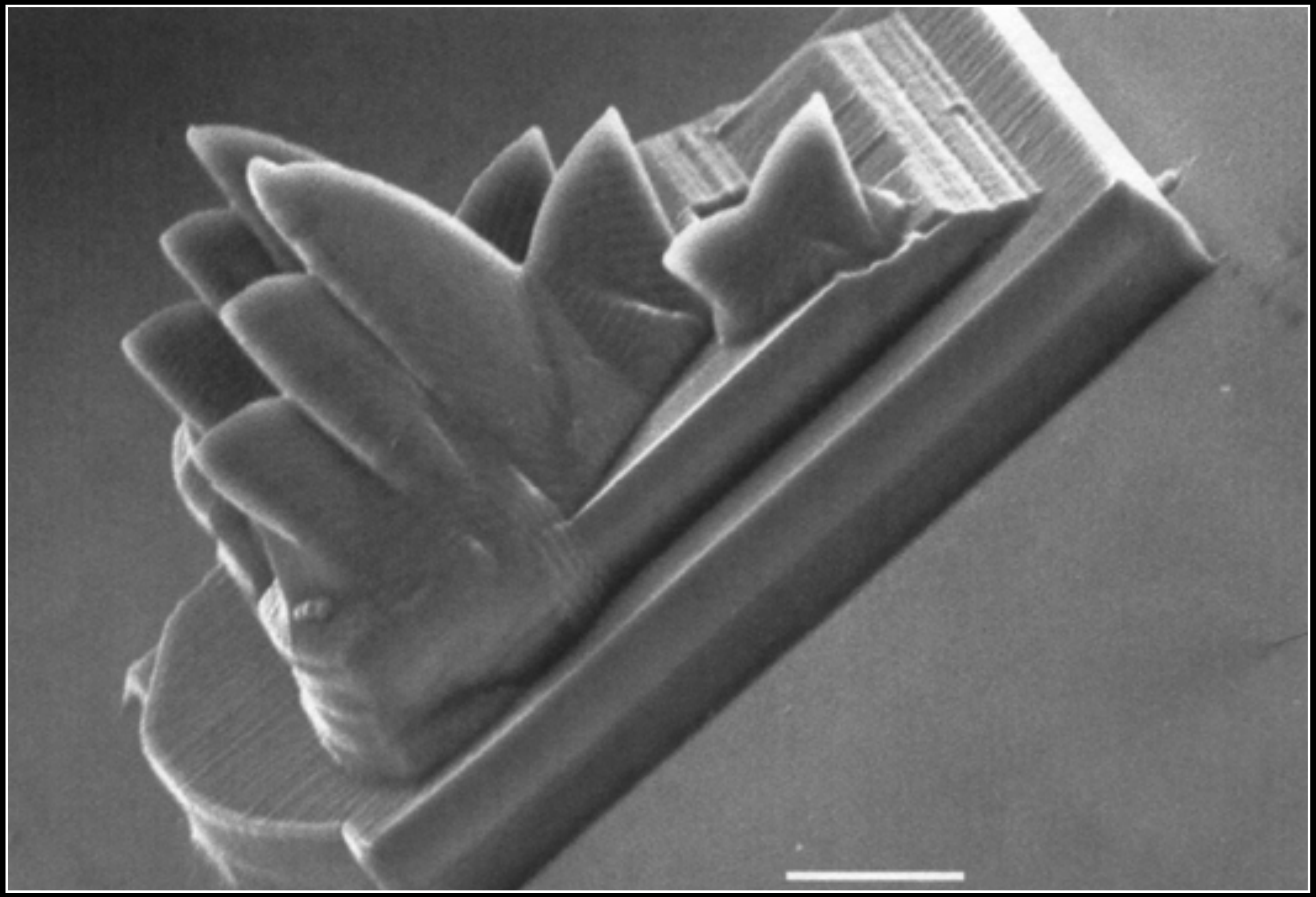






History - microscopic prototyping

- Photonics laboratory (Swinburne University)
- Building models at the micro scale.



10μm

Stereo Lithography

- First exposure to what we now call rapid prototyping was in 1995.
- But first machines were being created as early as 10 years before.
- Used photosensitive polymers that solidify when exposed to UV light. Hugely popular in engineering departments for prototyping parts.
- Monochromatic - low surface resolution - limited materials (1).
- Main issue was the requirement for supporting materials due to liquid nature of polymer.
- I missed the laminated surface printers, selective laser sintering, fused deposition modelling which all tried solve these limitations.

Z-Corp

- No colour and supporting structures were serious limitations for many/most data visualisation problems. So the first Z-Corp around 2002 was exciting.
- Got my hands on Z-Corp printer at an engineering firm who had the very first machine to be delivered to Australia.
- Finally we had colour (of a sort)!
- Working at Swinburne University on various educational 3D movies.
- Tested the printing of character models from the movie on the Z-Corp with the view of creating injection moulds.
- Other limitations: main one was fragility of model until cured.




Limitations, in the context of data visualisation

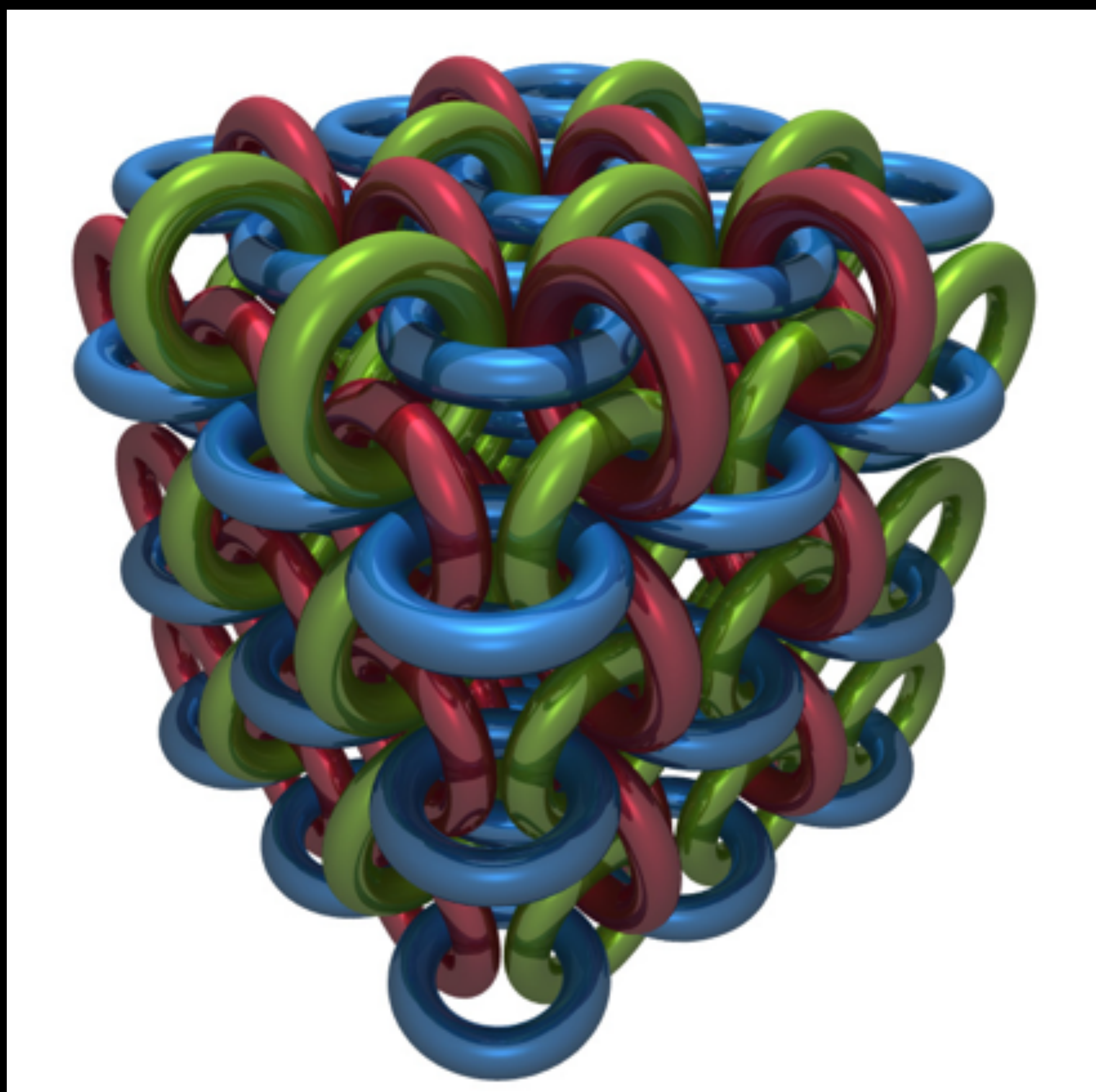
- What we now call 3D printers, arose largely from rapid prototyping in the engineering industry, notable the automotive industry.
- Typical pipeline is the creation (model in 3D) parts which are printed for evaluation, selling ideas and sometimes testing (eg: aerodynamics).
- A knowledge of the RP technology would influence model.

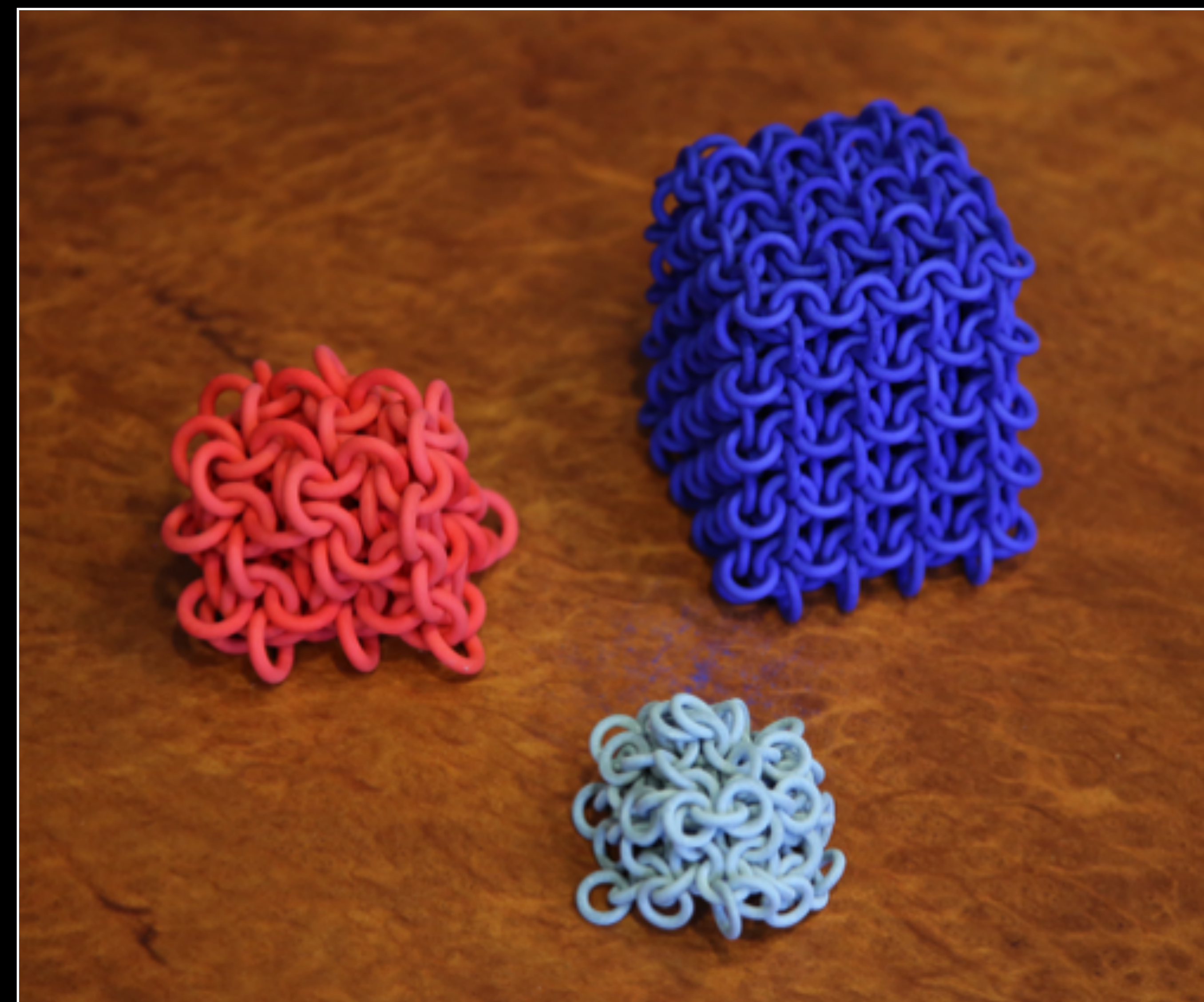
- The use by those of us interested in the data visualisation possibilities is not that different.
- EXCEPT, our data exists rather than being modelled.
- Data needs to be converted to printable geometry.

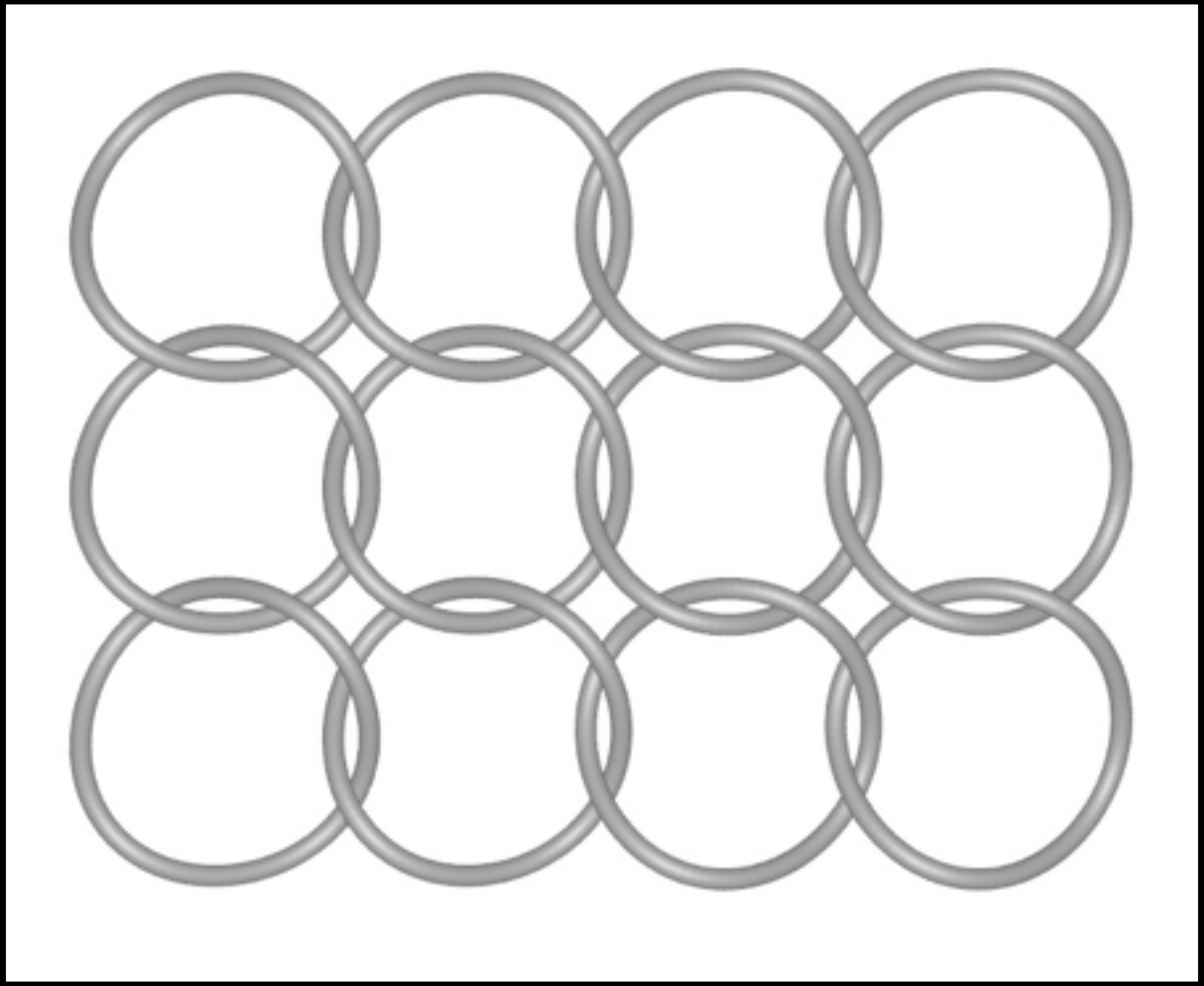
Limitations

Printer limitations	Data limitations
Self supporting structures	Precludes some data forms especially especially if the supports need to be removed manually
Connectedness	Not all data is in one piece
Minimum structural thickness	Limits geometric representation
Minimum printable thickness	Limits geometric representation
Resolution, minimum printable layer	Limits data detail representation
Colour fidelity and reproducibility	Limits conveying parameters through colour
Limited choice of materials	Limited options for surface feel (smooth, rough, soft etc)
Cost	Limits physical scale of 3D representation, typically the cost is proportional to volume of printed material.

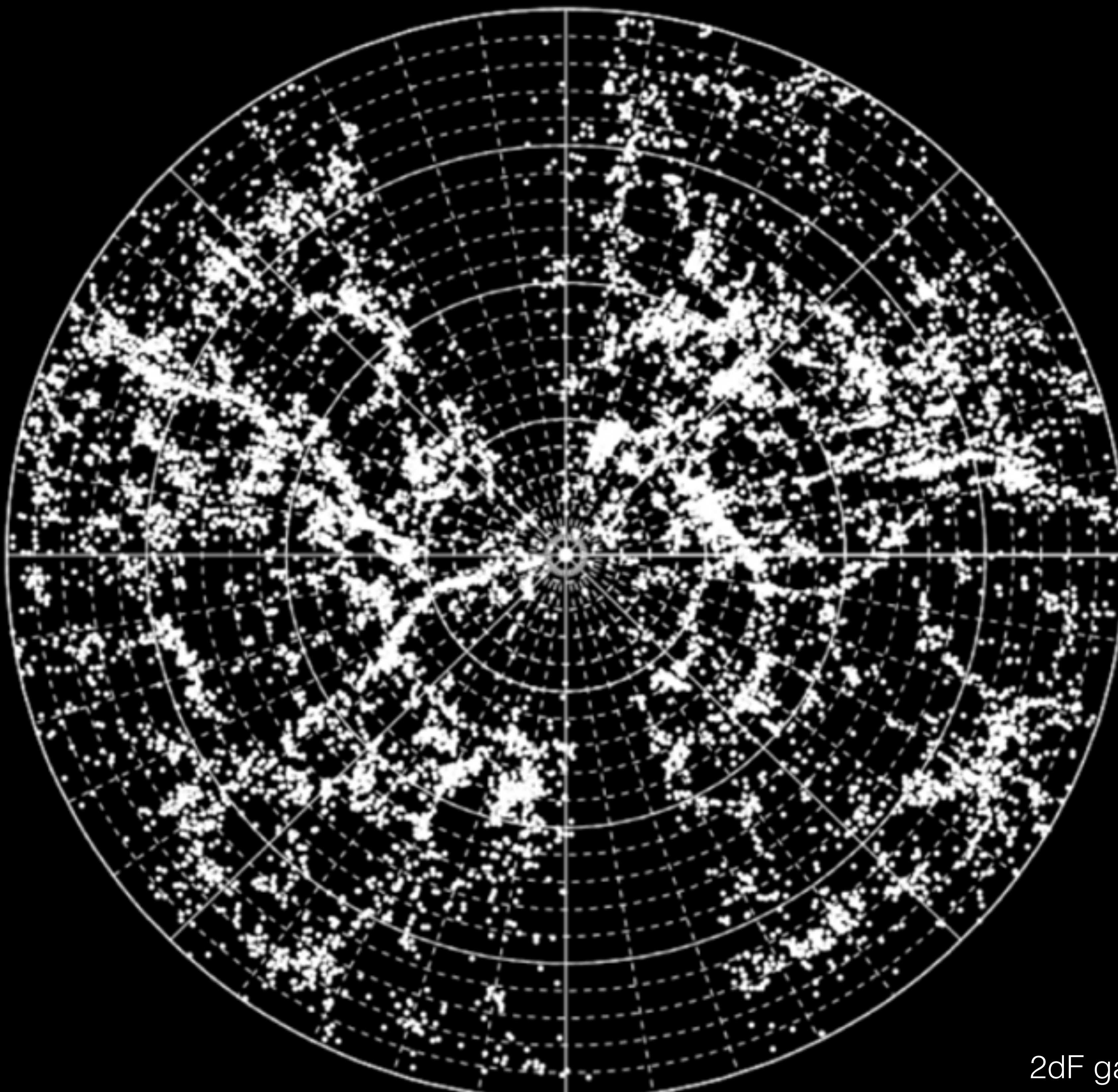
Self supporting structures



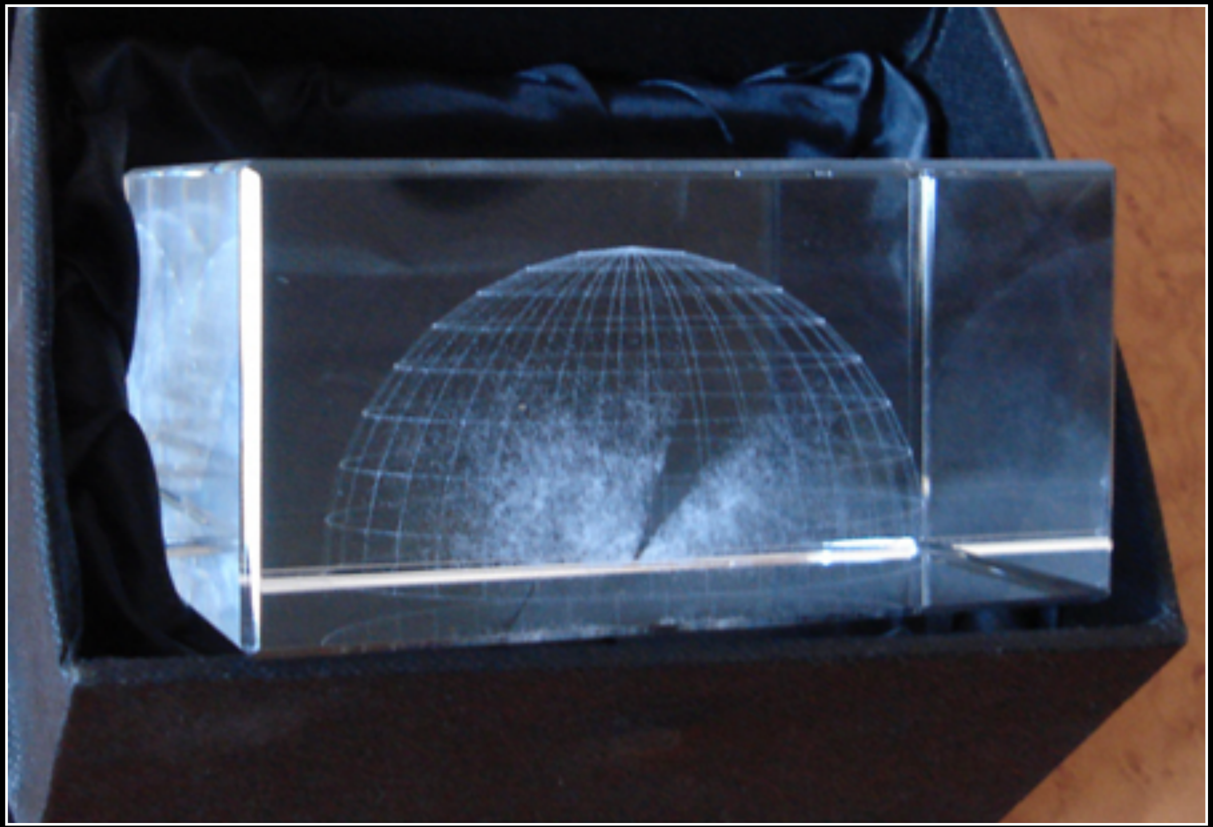




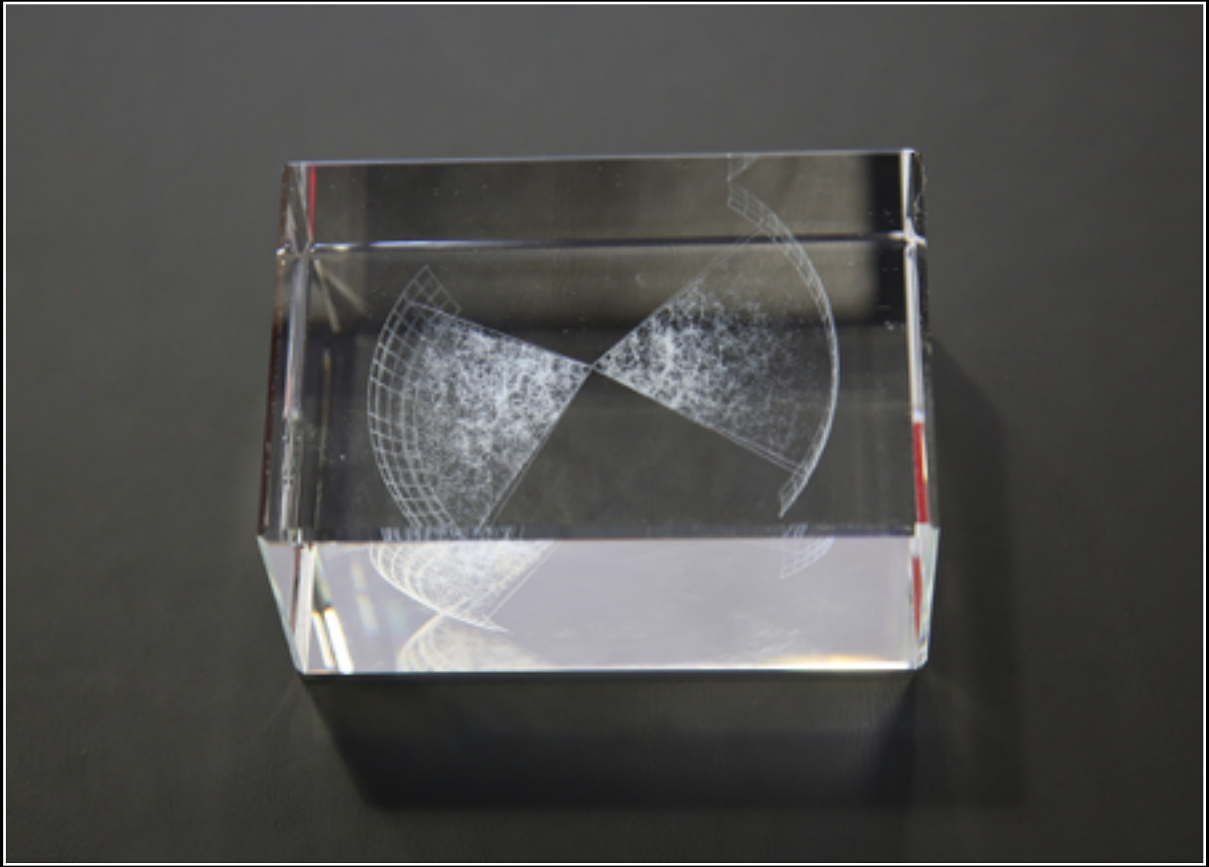

Connectedness



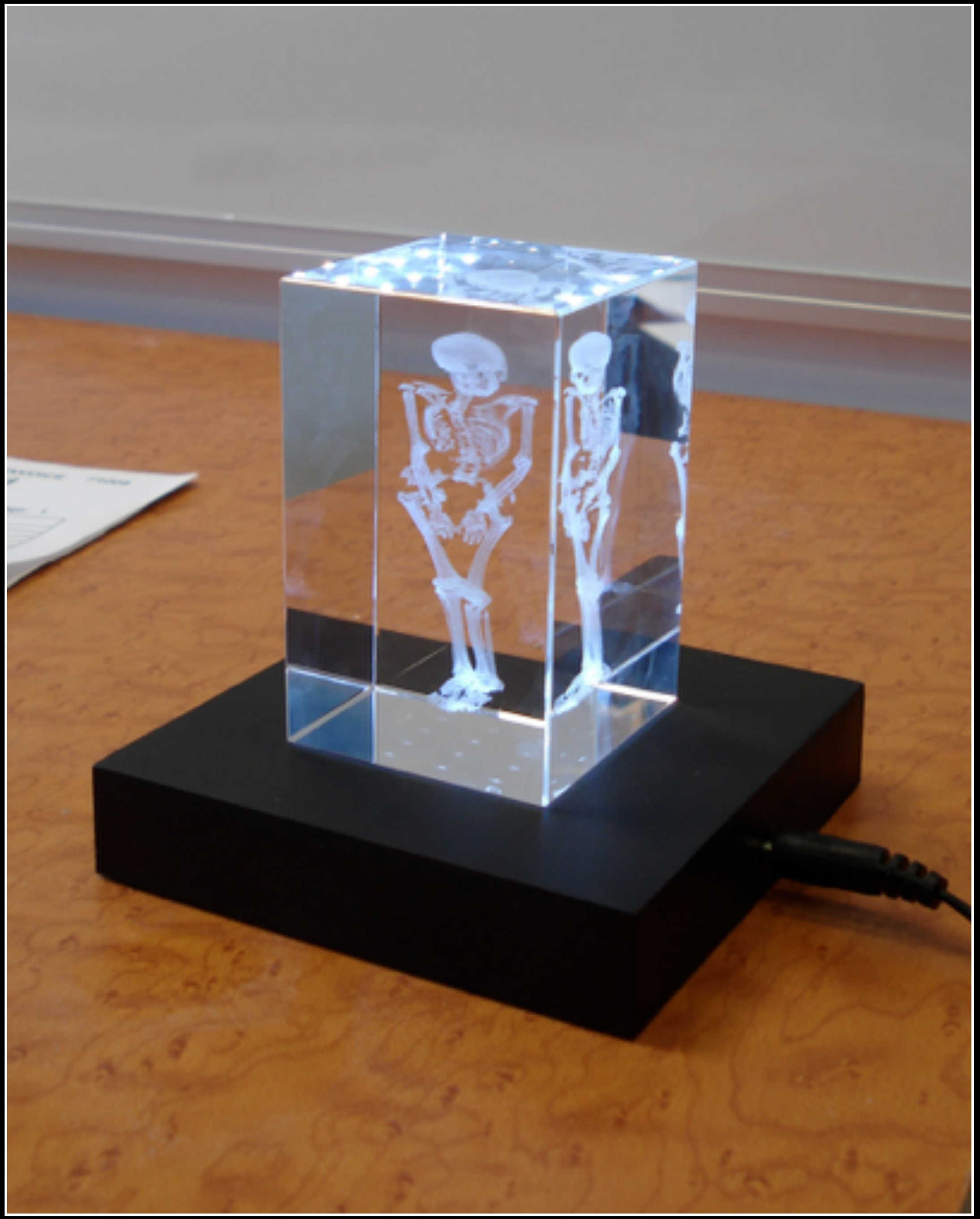
2dF galaxy survey



6dF

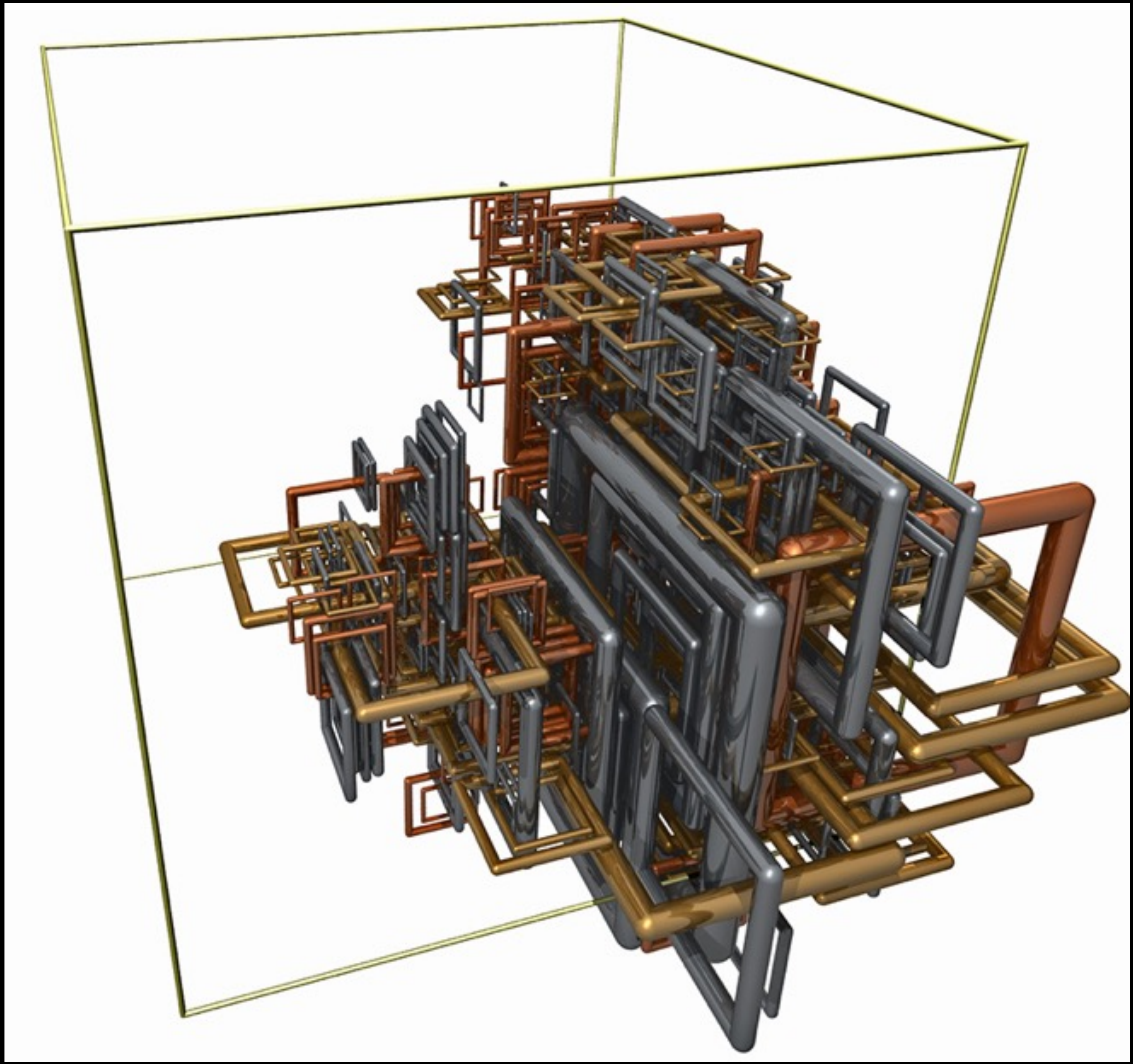


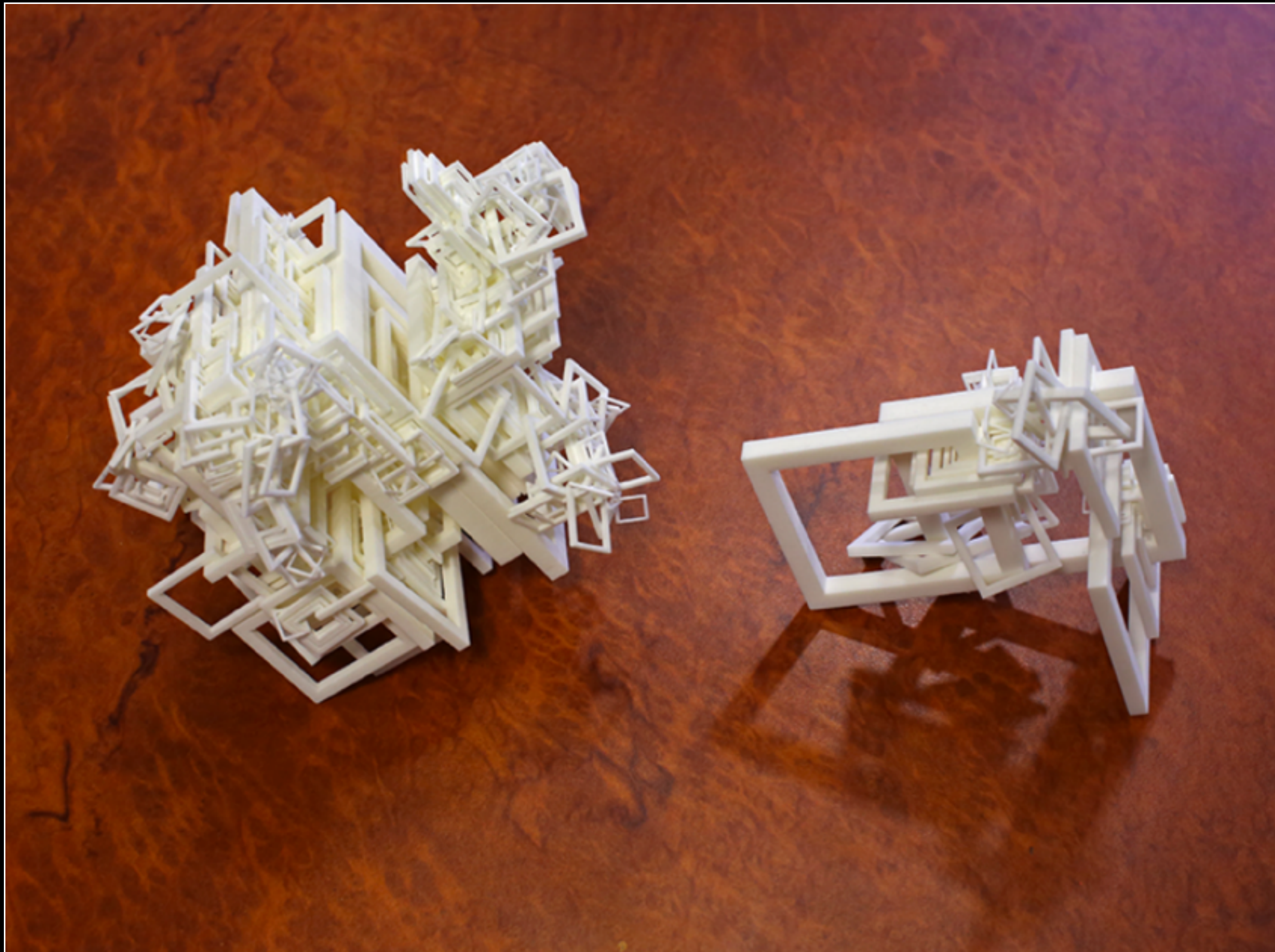
2dF



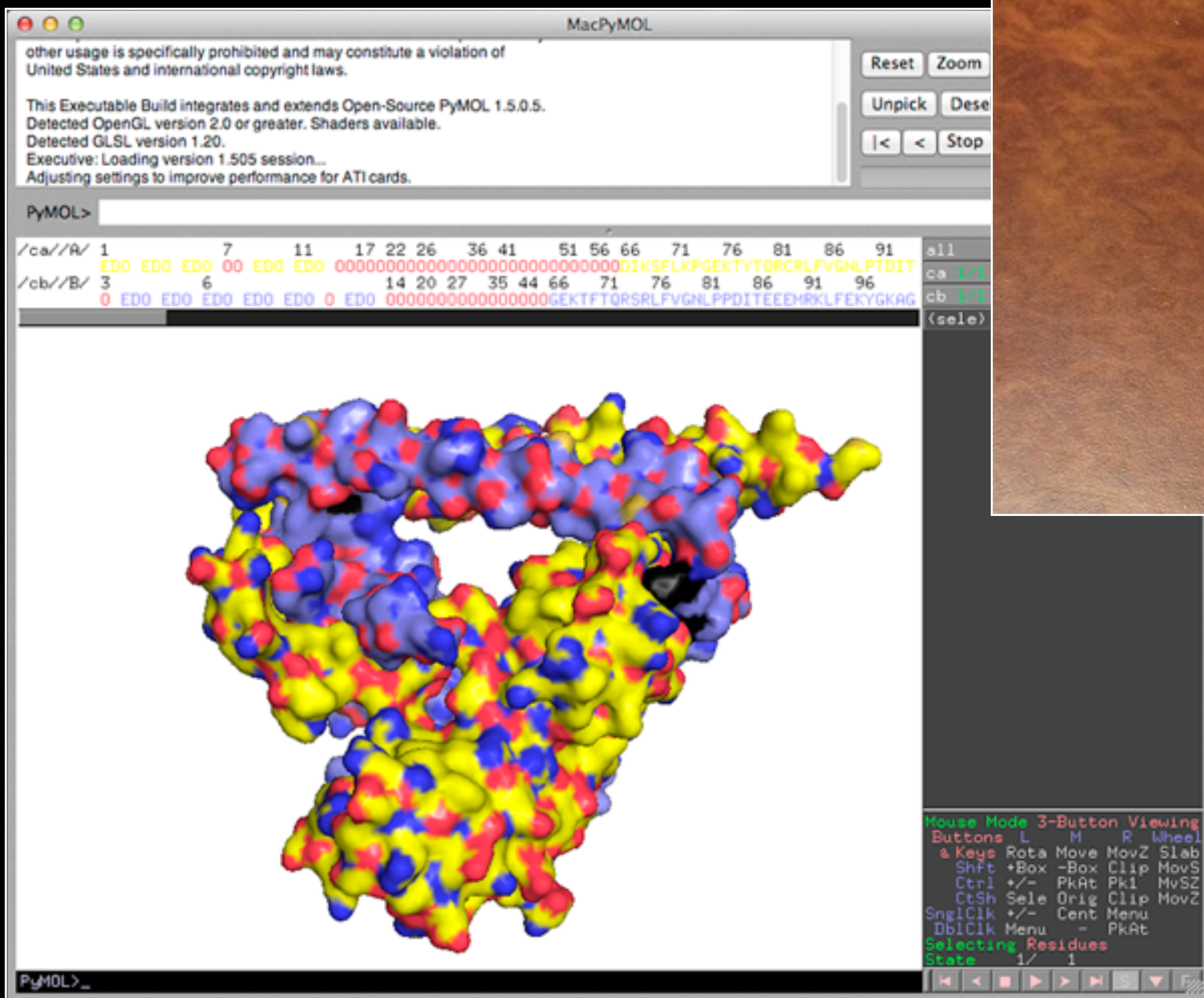
CAT scan of Egyptian

Minimal thickness





Colour fidelity


MacPyMOL
other usage is specifically prohibited and may constitute a violation of
United States and international copyright laws.
This Executable Build integrates and extends Open-Source PyMOL 1.5.0.5.
Detected OpenGL version 2.0 or greater. Shaders available.
Detected GLSL version 1.20.
Executive: Loading version 1.505 session...
Adjusting settings to improve performance for ATI cards.
Reset
Zoom
Unpick
Stop
PyMOL>
all
ca
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(sele)
Mouse Mode 3-Button Viewing
Buttons L M R Wheel
& Keys Rota Move MovZ Slab
Shft +Box -Box Clip MovS
Ctrl +/- PkAt Pk1 MvSZ
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DblClk Menu - PkAt
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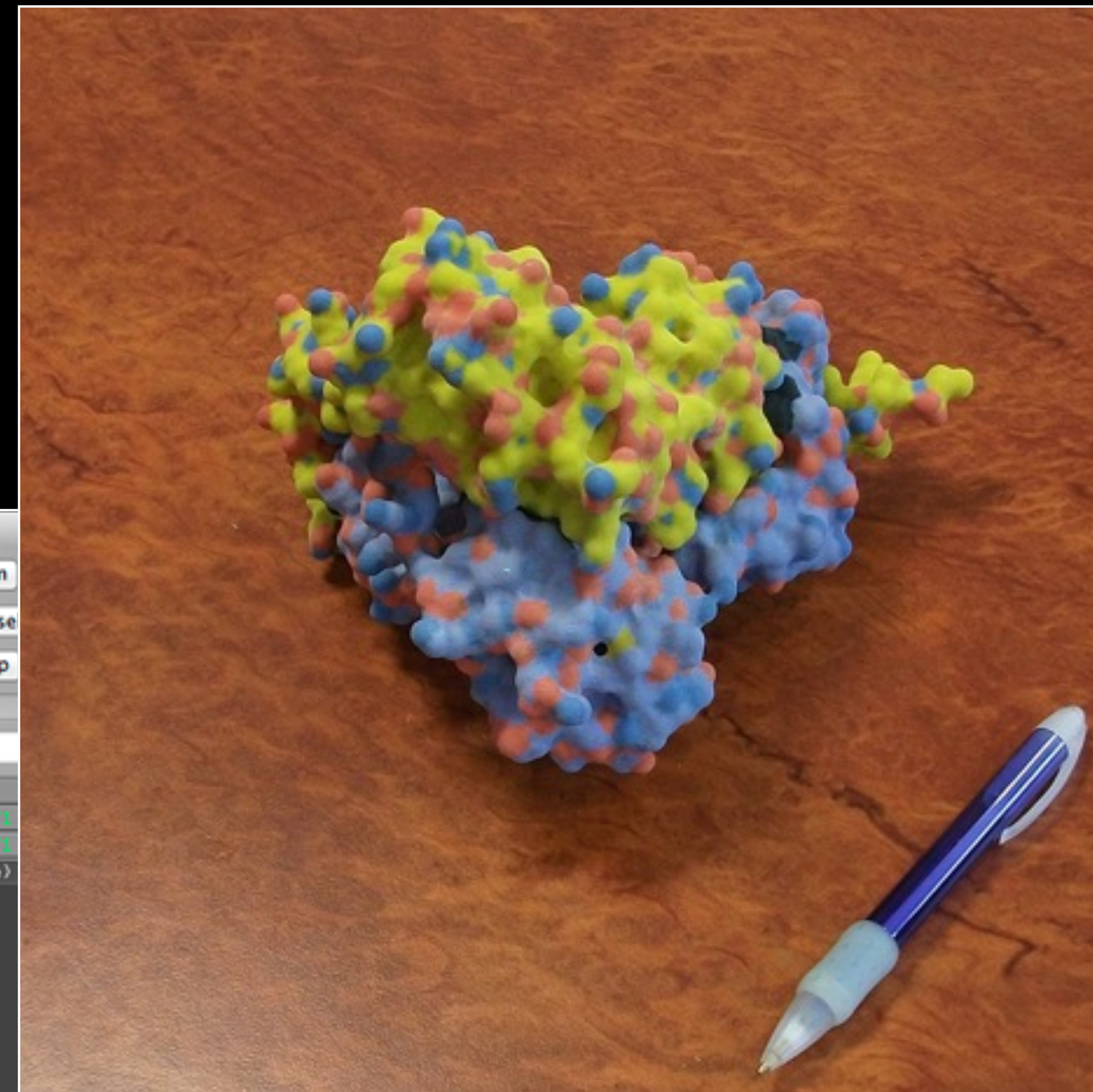
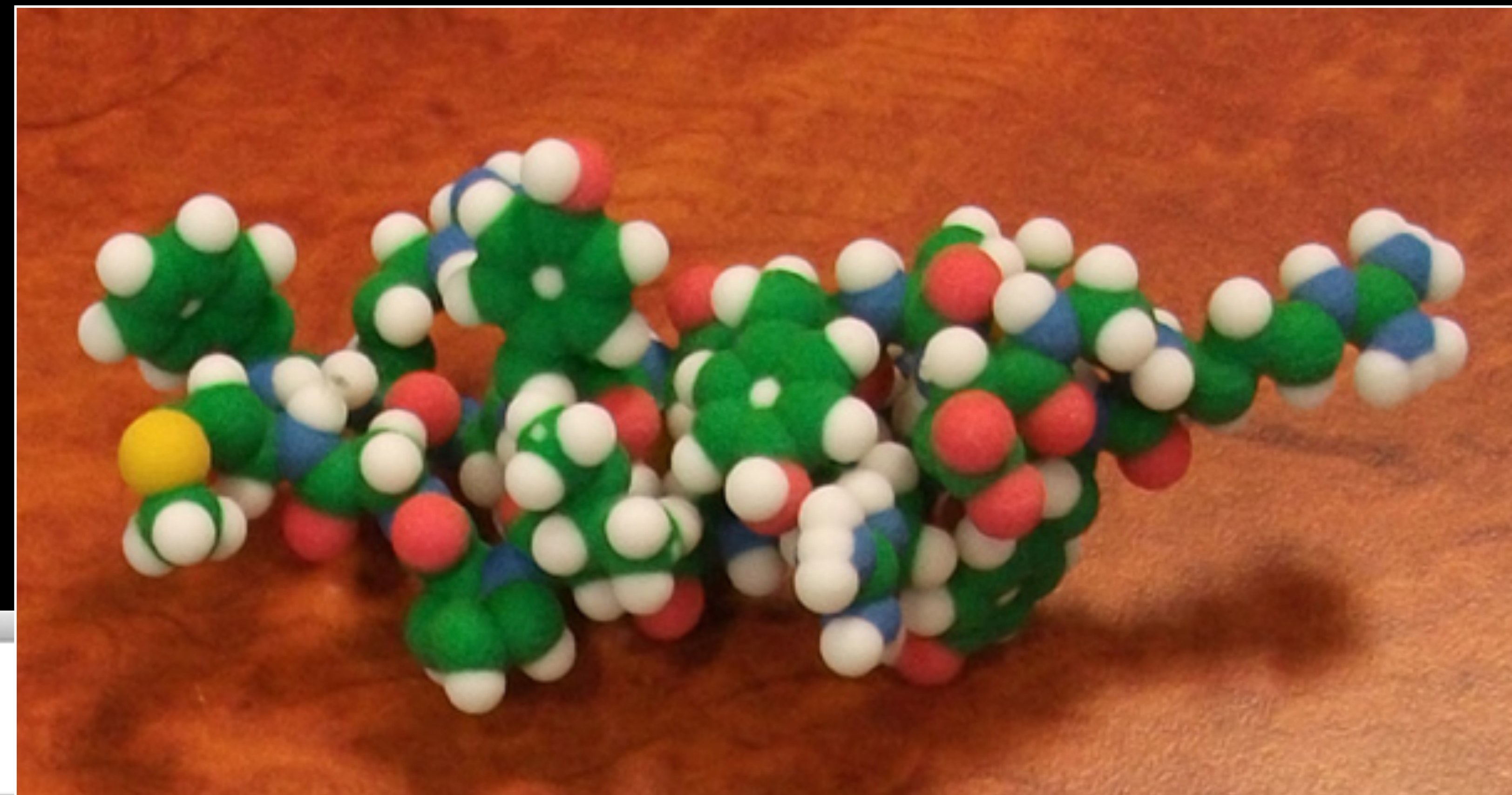
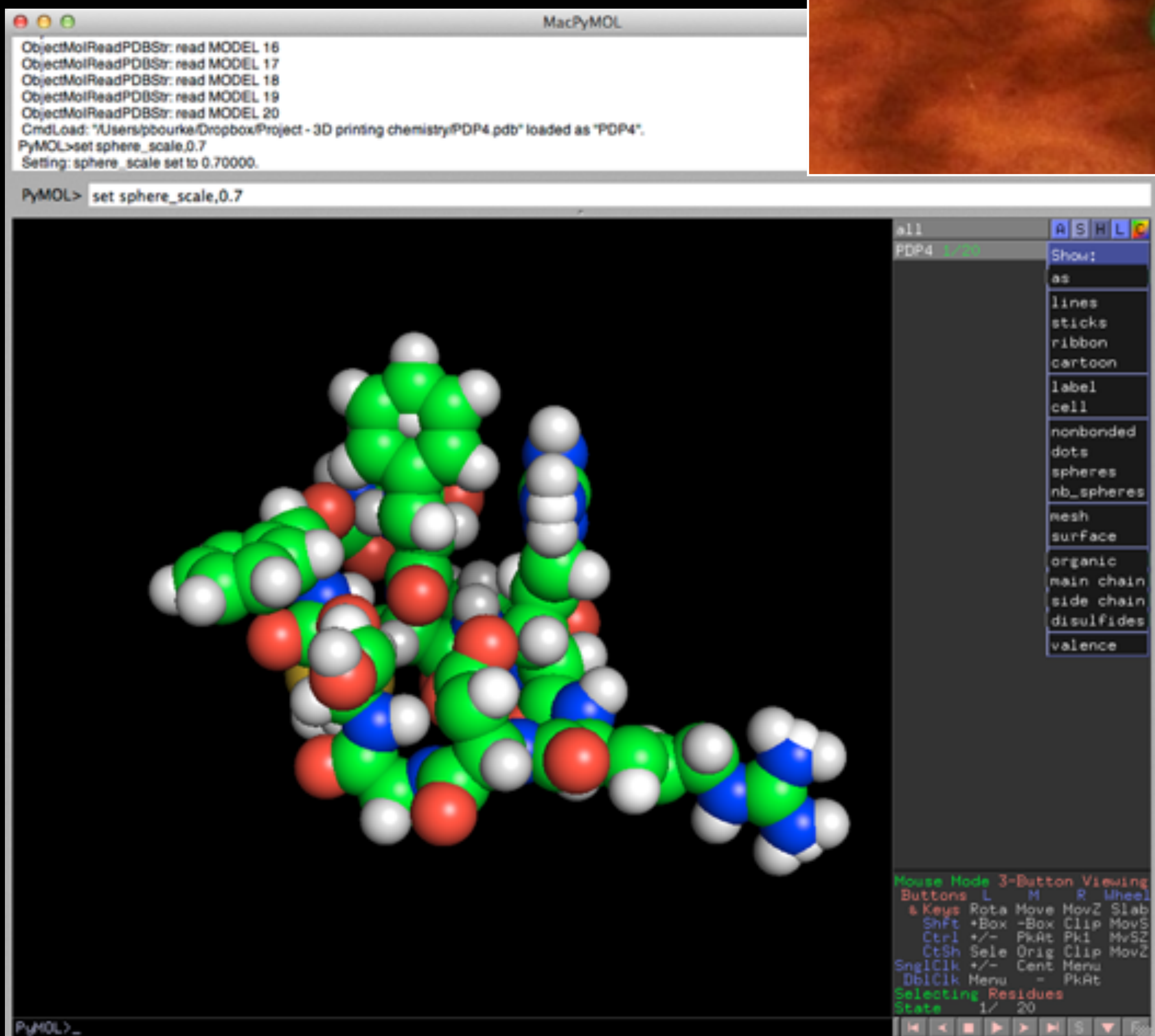
PyMOL>_

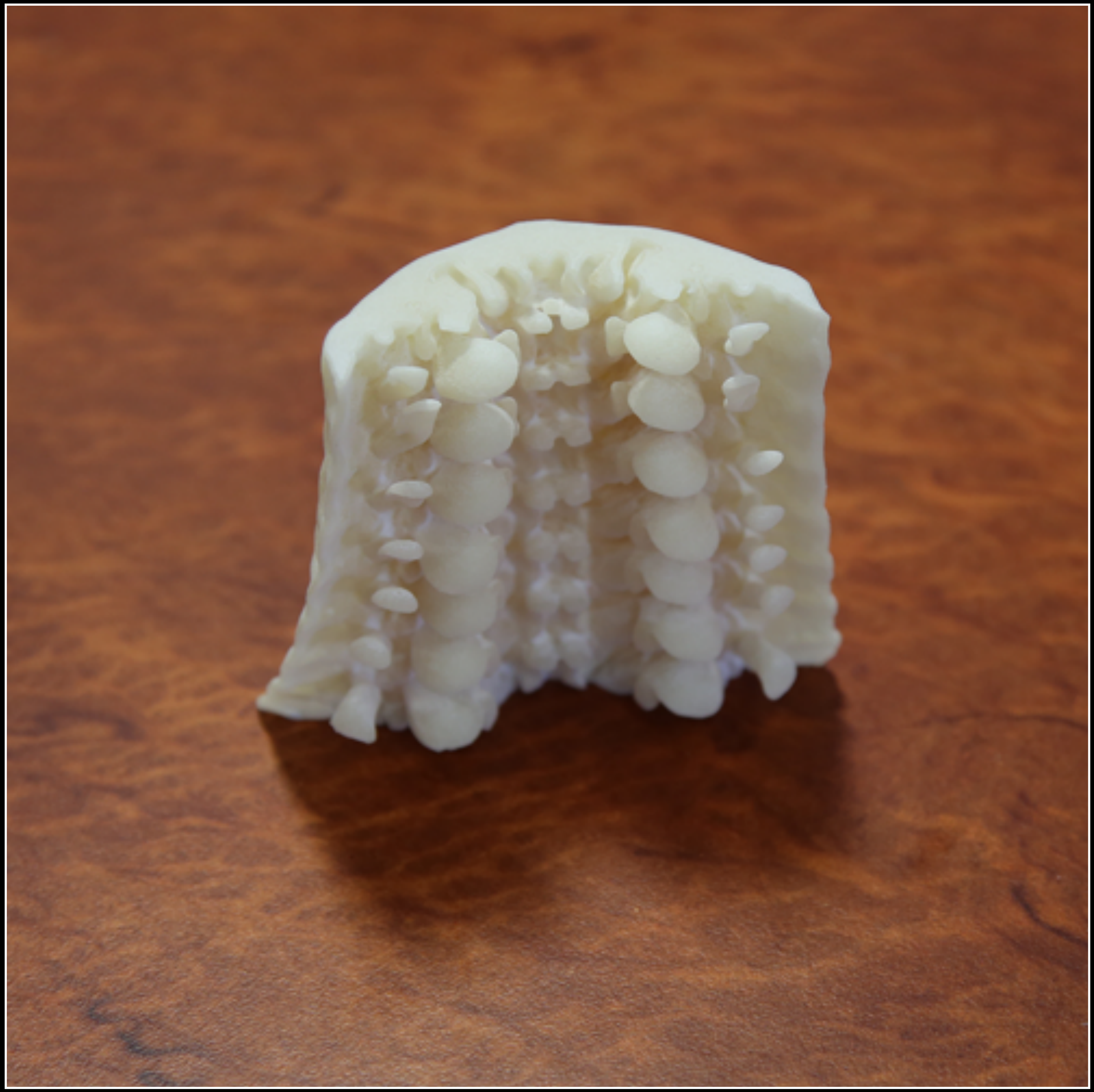




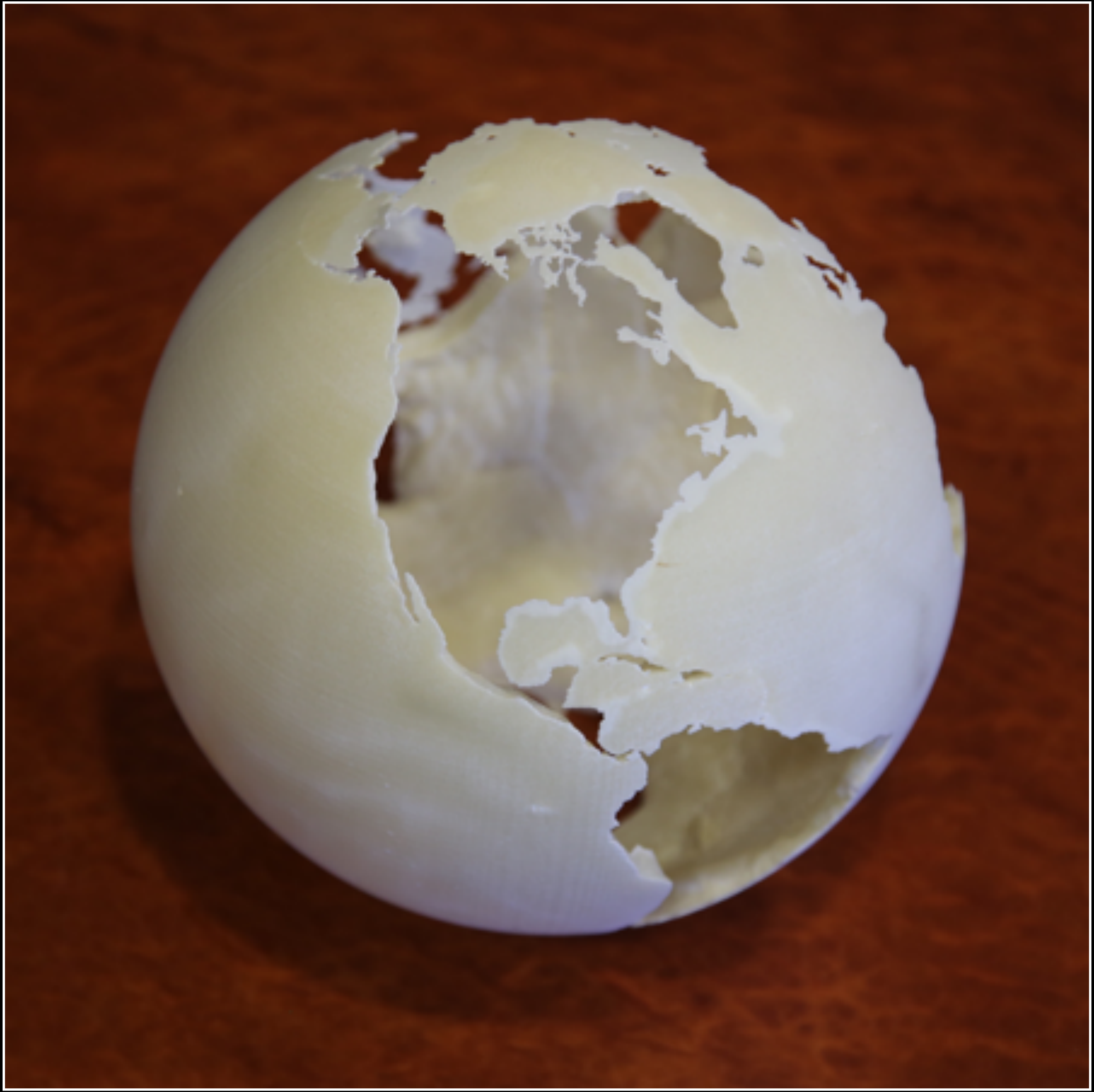

MacPyMOL
ObjectMolReadPDBStr: read MODEL 16
ObjectMolReadPDBStr: read MODEL 17
ObjectMolReadPDBStr: read MODEL 18
ObjectMolReadPDBStr: read MODEL 19
ObjectMolReadPDBStr: read MODEL 20
CmdLoad: "/Users/pbourke/Dropbox/Project - 3D printing chemistry/PDP4.pdb" loaded as "PDP4".
PyMOL>set sphere_scale,0.7
Setting: sphere_scale set to 0.70000.
PyMOL> set sphere_scale,0.7
all
PDP4 1/20
Show:
as
lines
sticks
ribbon
cartoon
label
cell
nonbonded
dots
spheres
nb_spheres
mesh
surface
organic
main chain
side chain
disulfides
valence
Mouse Mode 3-Button Viewing
Selecting Residues
PyMOL>_

Materials

- Radula of ancient snail. Isosurface from CT scan.
- Printed in soft rubbery material to reflect “flesh” nature.
- But would have liked the “teeth” to be hard surface.



Cost



Challenges

- I have not been involved in the development of the hardware.
- But rather converting data to be visualised into geometry suitable for 3D printing.

- Main challenge is mostly computational geometry to create geometry to deal with or overcome machine limitations.
- Software challenge, support 3D printing as standard output!

Software: Geometry

- Converting non printable geometric primitives into printable ones, lines and surfaces.
- Ensuring geometry doesn't contain holes or sliver gaps. (Manifold) Problem with a surprising number of isosurface algorithms.
- Ensuring a minimum thickness for all primitives.
- Dealing with minimum thickness requirements as models are scaled.
- Like VR all units should the real world, only way to ensure
- Understanding colour space and colour profiles to maximise colour fidelity. Handled quite poorly by current bureau services and software.
- Creating hollow objects to reduce volume and hence cost.

Software: File formats

- My tool set includes libraries to support the three most common formats. Limited myself to non-proprietary, text/human readable formats.
- STL - Dumb but easiest for non colour. Only has one primitive, a triangular face.
- VRML - Old and messy but commonly supported for simple colour. Unfortunately most higher level primitives are poorly supported.
- OBJ - Old but simple and efficient. Preferred option for textured models e.g.: Rock art models
- Other options might be X3D, 3ds, Collada (standards based) …. depends on support by 3D printer being used. Generally more complicated than necessary.
- None support high level primitives such as spheres and cylinders!

Software: Functions

- Typically support the following:

- File open and close.
  Write file header and footer.

- Create a triangle or quad (later may be just two triangles).

- Create a sphere or cylinder (to represent points and lines).
  Includes ellipse.

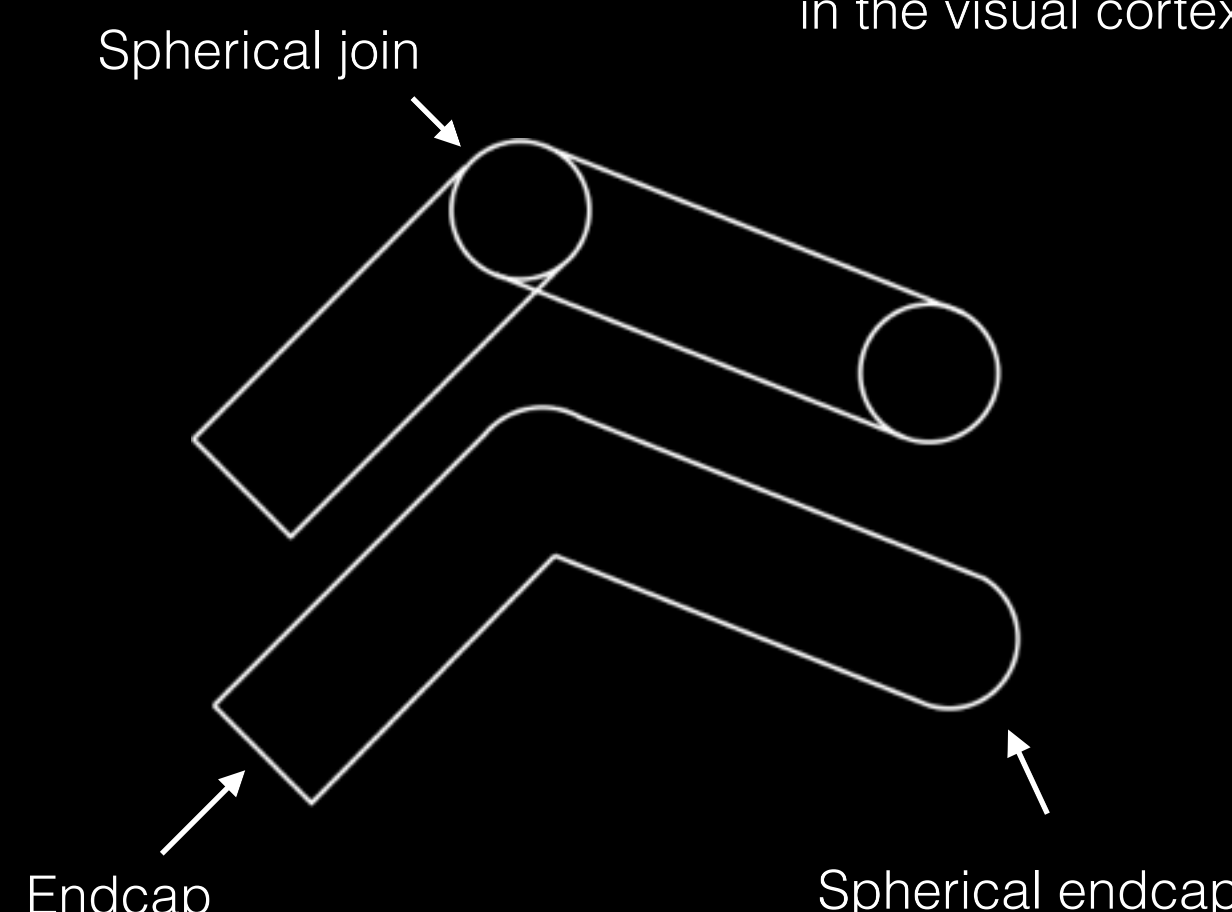
- Higher level primitives
  - Create a curve, bezier/spline/linear of specified radius.
  - Create a mesh surface of specified thickness.

- Optional depending on format (adding as required)
  - Create a box
  - Create a cone (cylinder with different end radii)
  - Create triangle or quad with thickness

Software: Lines and curves

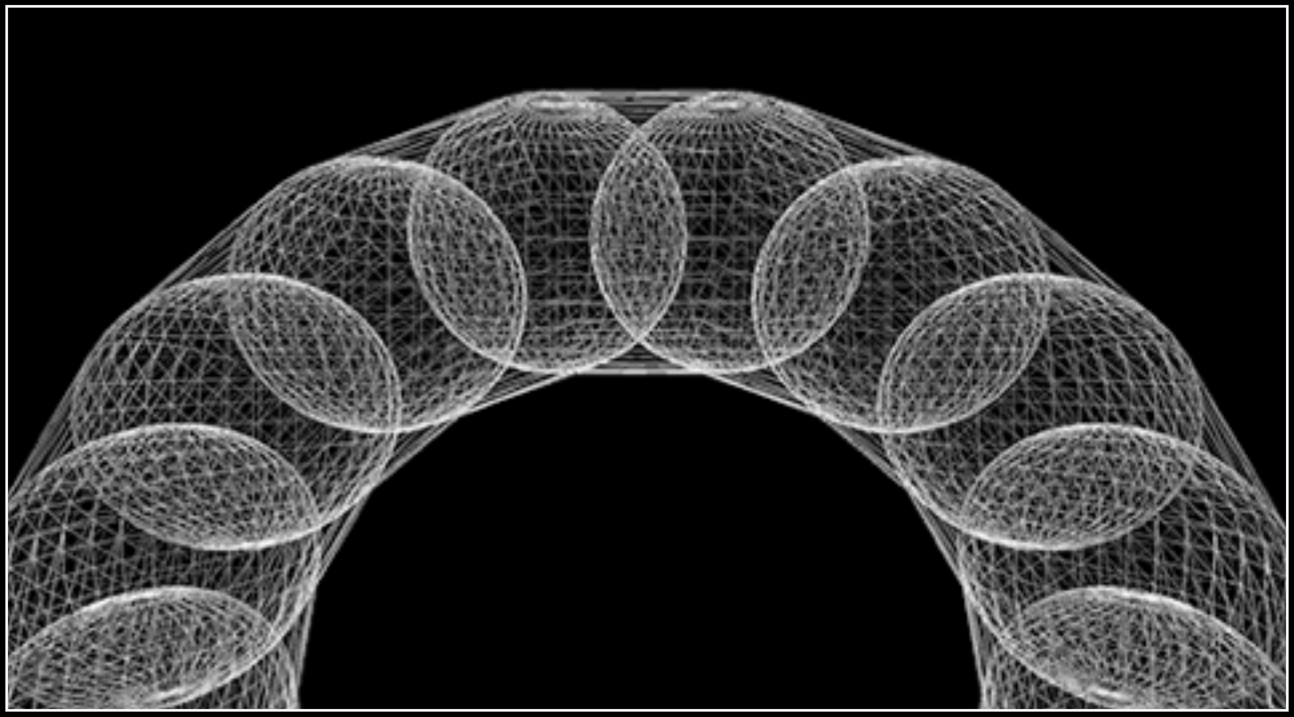
- Lines and curves are infinitely thin, cannot be physically realised.
- Need to be represented as meshes, collections of facets (triangular bounded plane sections).
- Approach is to turn lines into cylinders and seal them with spheres or endcaps.
- Can result in a very large number of triangular faces.

Model for connectivity in the visual cortex.

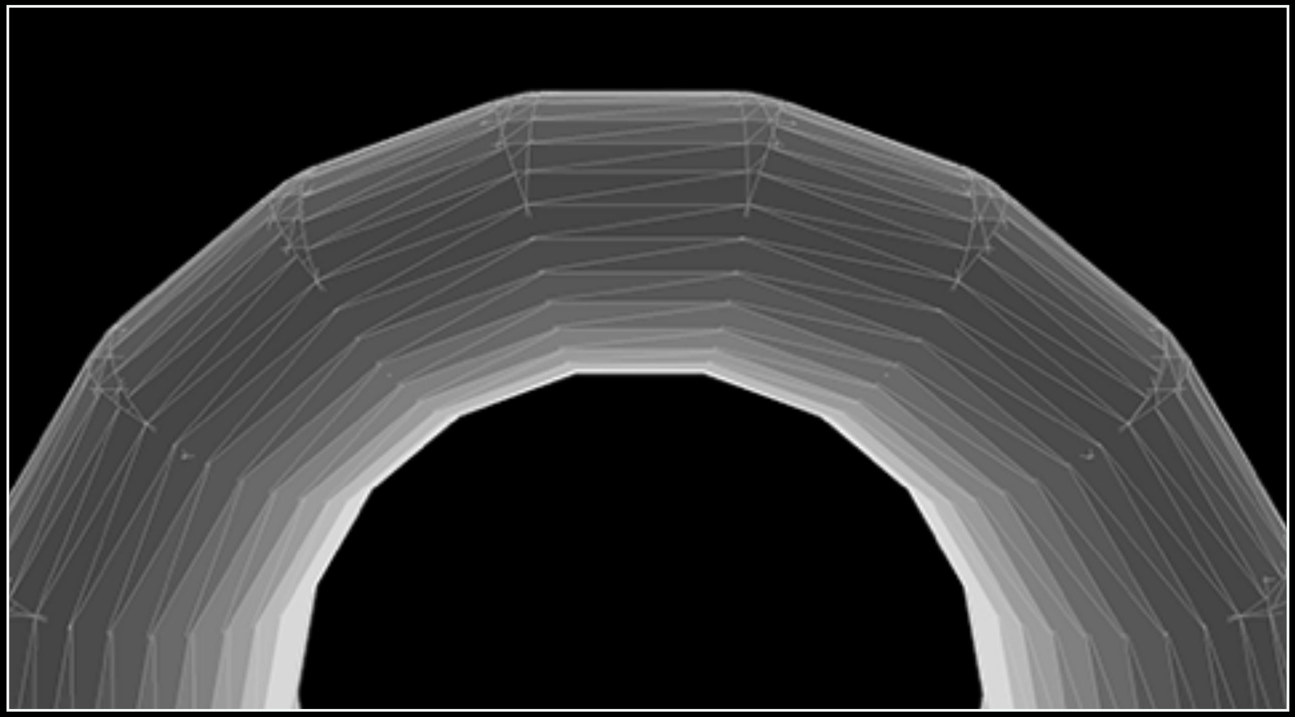


Software: Lines and curves

- Lines and curves formed as a large stack of spheres. Inefficient but easy.
- More efficient to create spheres at vertices and cylinders between spheres.
- Interior geometry is inefficient but otherwise does not affect the model.
- Ideal, most efficient is cylindrical sections cut back at (internal) concave side and extended across (external) convex side. Can have issues with high sharp corners.



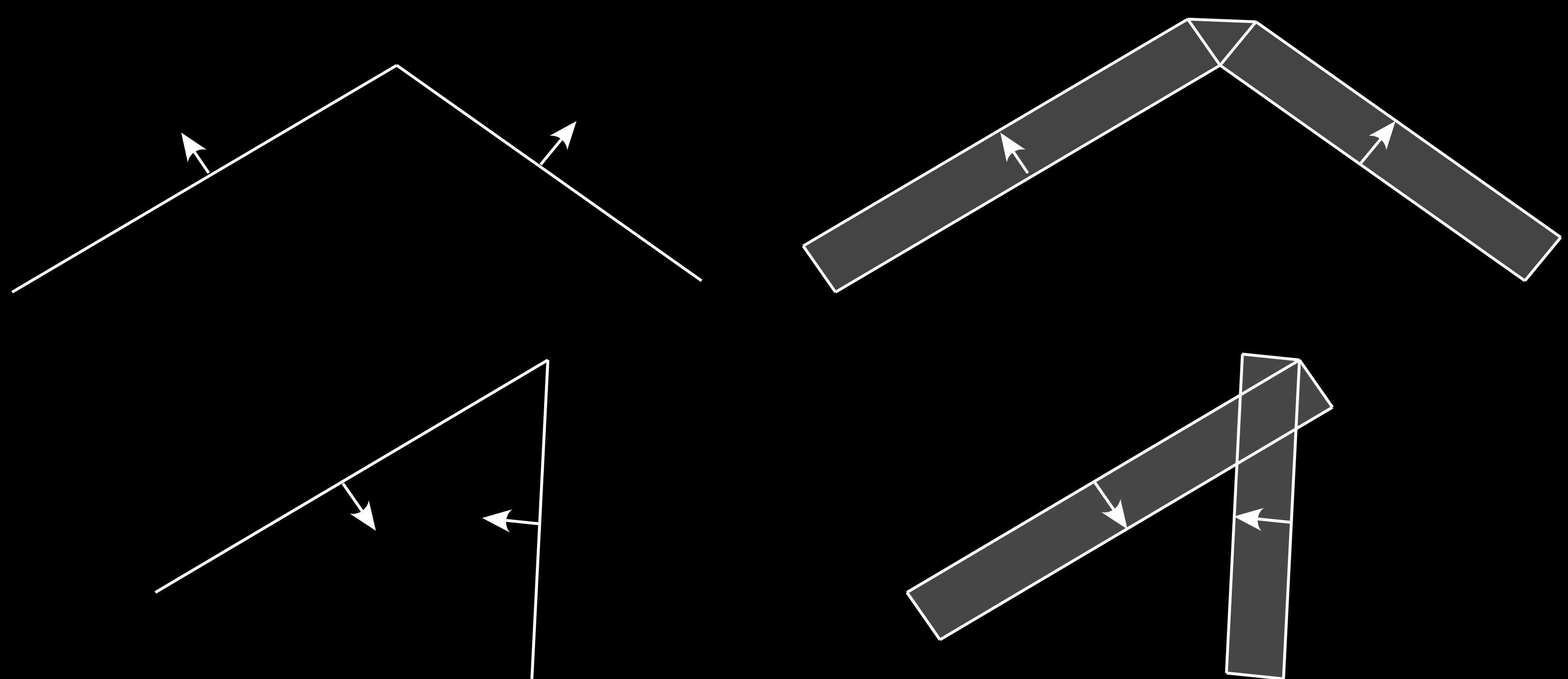
Spheres and cylinders



Cut and extended cylindrical sections

Software: Planes and surfaces

- A surface / mesh in 3D computer graphics, like an idealised point or line, is infinitely thin. As such is unrealisable physically.
- A triangle/quad/mesh then needs to be “thickened” to some minimal thickness in order to be printed.
- One might imagine the solution is to extrude the triangles making up the mesh along their normals. This simple approach can have issues for areas of high curvature.

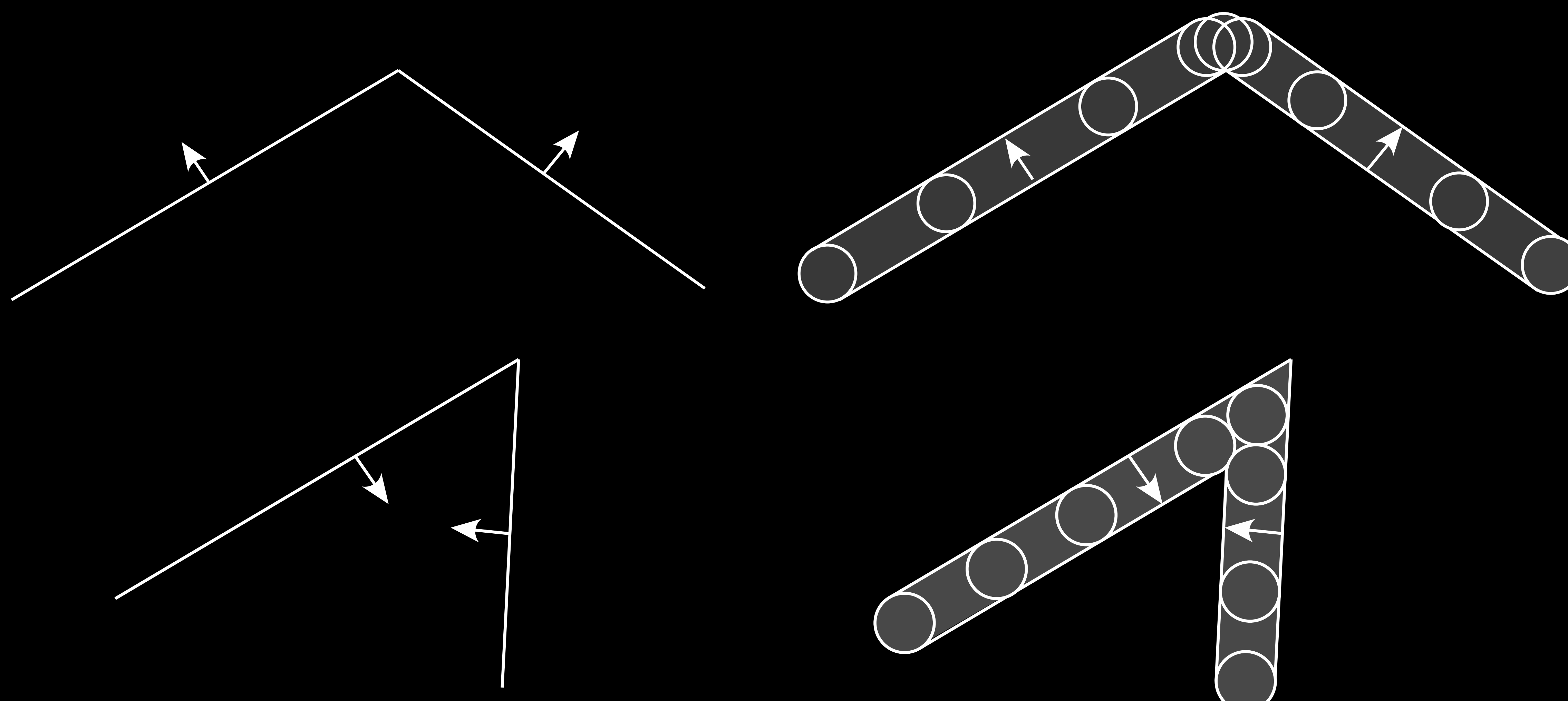


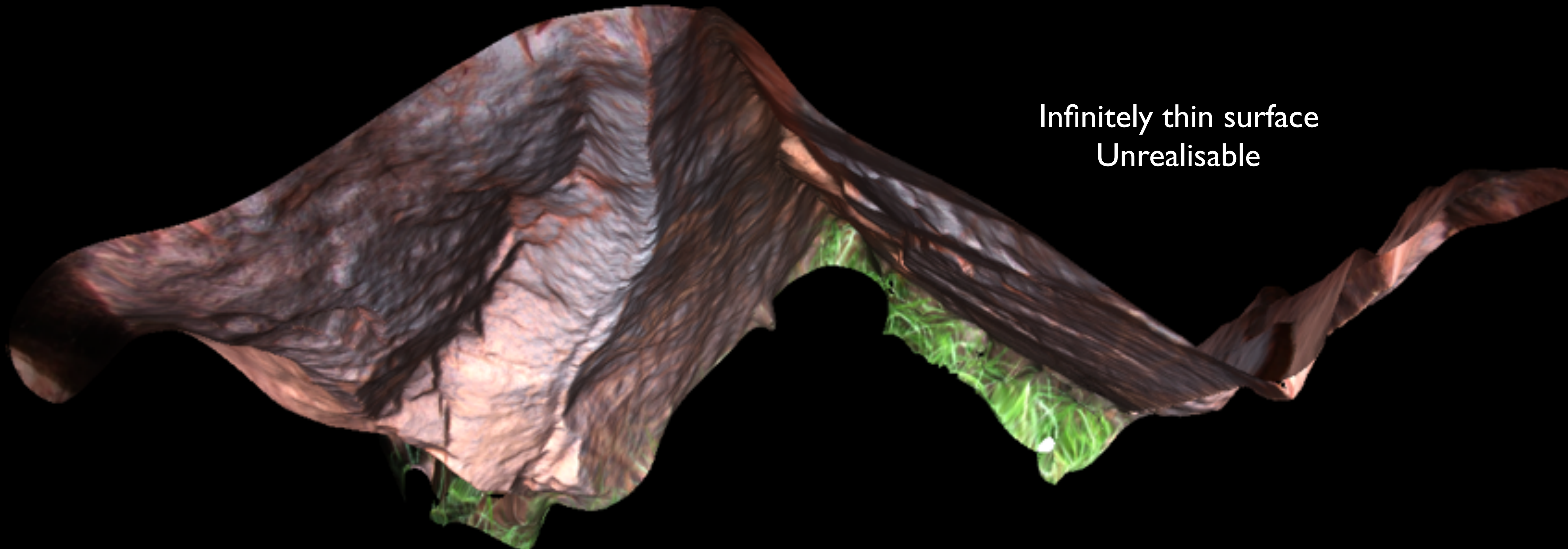
Thin joints arise at regions of high curvature

Get “poke-through” with sharp concave interiors

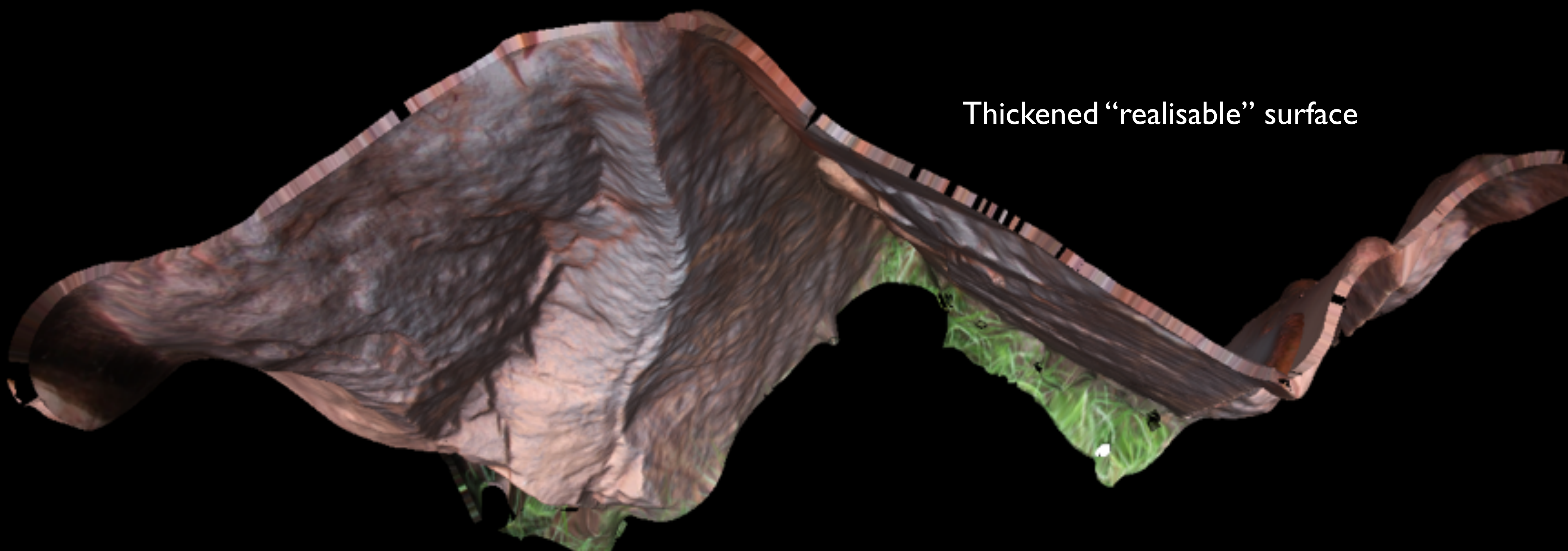
Software: Planes and surfaces

- Solution is called “rolling ball” thickening.
- Imagine a ball rolling across the surface, form an external mesh along the ball path.
- One solution is to form point samples and employ 3D Delauney triangulation to form the solid surface.
- Another solution is to form a volumetric set and take marching cubes style isosurface.



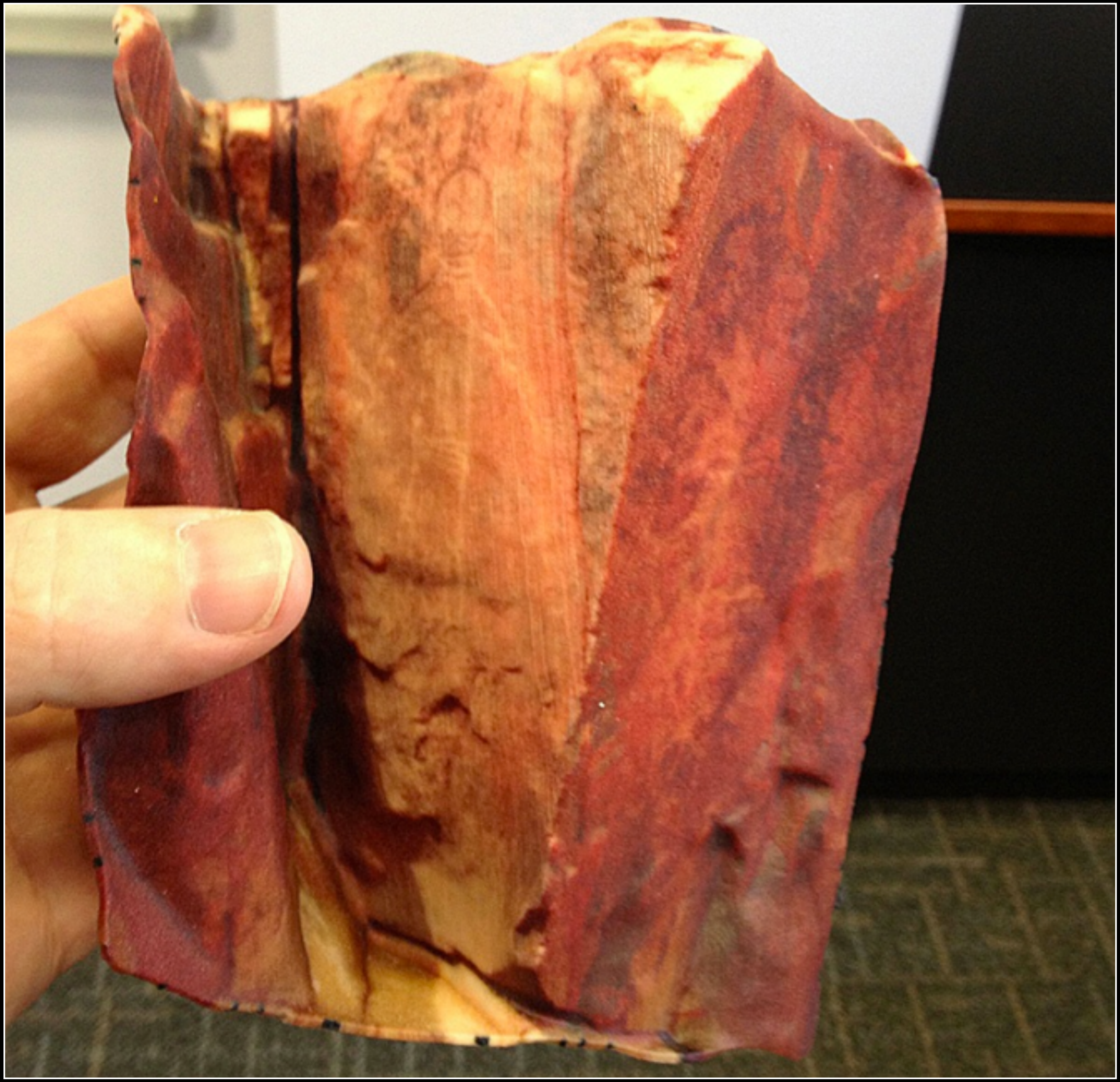


Infinitely thin surface
Unrealisable



Thickened “realisable” surface


G07
Paul Bourke



Random final comments

- To own or use commercial bureau services?
  - Cost of ownership if one has low volume.
  - Staff for effective operation.
  - Turn around time.
  - There are multiple technologies each with different advantages.
  - New technologies are still being developed.

- Exciting recent printers that can create solid models with different colour layers and clear “glass”. (eg: Object Connex3)
  - Current lack of bureau services.
  - High price point.
  - Cost, both for machine and models.
  - Opportunities for volume visualisation and solving connectivity limitation.

Questions ?


C&H
GRANULATED SUGAR
50 LB.

+


CAUTION
AOYUE Int 850A
POWER
ON
OFF

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