

# Tactile Visualisation: Feel your data!

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- Motivation
- Technology
- Discussion

Acknowledgement: Joe Sandon, CSSE, UWA

## Visualisation - Vision centric

- Science visualisation: Present data in such a way as to assist in the understanding of the underlying principles/ processes.
- Data may be sourced from experimental measurement (acquisition), simulation, or mathematics.
- Traditionally only employs our visual system.
- May include stereoscopic techniques to exploit our depth perception.
- May use immersive environments to exploit our peripheral vision.
- May use virtual reality (head tracking, 3D interface devices, etc) to increase the observers engagement with the data.

What about our other senses?



# Smell / Taste

- Difficult to imagine an informative mapping between data and smell/taste.
- Unable to (reliably) synthesis odors.
- Not a precise sense.
- Highly subjective, significant variation between individuals.
- Has a high degree of habituation, we subconsciously block out continuous or unpleasant odors.
- Note the reverse has been attempted, visualising odors using visuals or music.

# Hearing

- Sonification : Generation of audio from data (excludes speech).
- Simplest examples are the Geiger counter and medical monitoring (machine that goes “ping”).
- Volume mapping (soft to loud), pitch mapping (low to high frequency), instrument mapping (eg: midi).
- Generally a very loose/imprecise relationship to the data except for time series.
- Potential for representing spatial relationships.
- Sonification most commonly used to enhance a visual experience.
- Most common in support of scientific visualisation for exhibitions and movies.

Pulsar example



# Touch: Haptic / force feedback

- Application of forces to give a sense of touching (hitting) a virtual object.
- Quite a coarse sensation, usually limited to a single point of contact.
- Most commonly used as a human-computer interface, eg: teleoperation.
- Employed in gaming, eg: force feedback joysticks and steering wheels.
- Some experiments have mapped data to temperature.
- Vibrator pads can give a sense of surface properties (eg: roughness, hardness).
- Still a very different sensation to holding and feeling objects in real life.



# Touch

- We regularly explore objects during our everyday life by using our hands, usually in conjunction with our eyes.
- We hold objects and turn them around with our hands to see/feel different sides.

Can we do this to datasets?

- We are already familiar with the conversion of data into geometry which is then rendered for our visual sense.

Can we take the additional step of turning data into a physical object which can then be explored with both our sense of touch and vision?



# Rapid prototyping technology

- “Rapid prototyping”: the automatic construction of physical objects.
- Intended primarily to speed up the model making cycle for new products and components. The term “rapid” is relative, generally rapid compared to a human tool maker or sculptor.
- The vast majority of the techniques are referred to as additive fabrication, that is, the 3D model is built up by thin layers.
- Three main technologies: selective laser sintering, fused deposition, stereolithography. There are others but they are more exotic and outside the scope of this discussion.
- Considerations
  - resolution, accuracy
  - requirement for self supporting structures
  - durability
  - support for colour and/or transparency
  - ability to create both rigid and flexible models
  - support for multiple materials within a single model
  - operating environment

## Selective Laser Sintering

- Uses a high power laser to fuse small particles together, layer by layer.
- There are a variety of materials that can be used: plastics, powders, ceramics, metals, etc.
- Because of the wide range of materials it is often capable to creating final products rather than just prototypes.
- Very similar to the ZCorp process (see later) except it uses a laser rather than glue.
- There is an inverse process call Selective Laser Melting that removes material from a solid block.

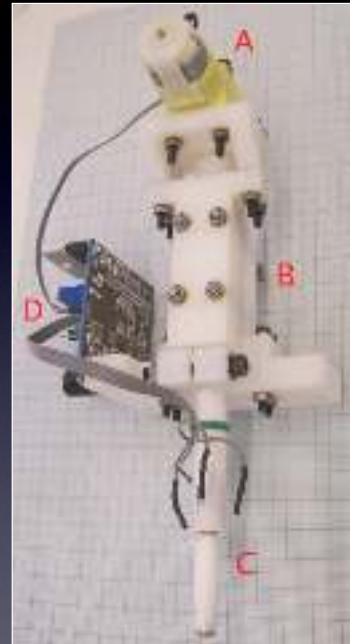


# Fused Deposition

- A nozzle squirts a (melted) plastic or metal wire.
- While in theory the nozzle (extrusion head) can have 6 degrees of freedom (any position and orientation), most commonly the model is still created in layers.
- Some machines can use multiple materials to form one model. This can also be used to create water soluble (for example) support structures when necessary.
- See the “RepRap project” (Opensource), the goal is to create a machine that can manufacture all of it’s own parts.



Illustrate the problem of supporting structures



# Stereolithography

- Uses a liquid polymer that solidifies on contact with a UV laser beam.
- Polymer/resin level slowly rises as the layers are traced by the laser.
- Main limitation is the need for supporting structures and limited support for colour.
- Quite popular for medical applications, custom implants, prostheses, and pre-operative planning.



# ZCorp rapid prototyping machine

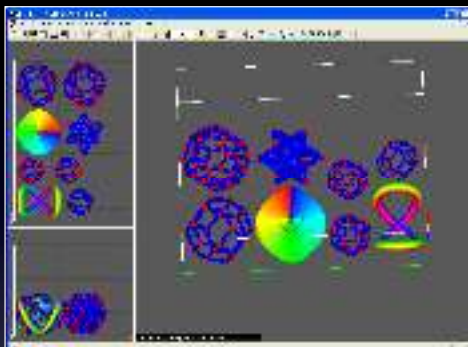
- Glorified ink jet printer.
- Deposits binding agent (glue) instead of ink over layers of fine powder.
- Simple extension to deposit coloured binding agent.
- Spectrum Z510, 3 colour and clear binding agent.
- Main advantage over other technologies is the ability to create non-self supporting structures. The powder acts to support new structure.



CSSE, UWA

- Will restrict the remainder of the discussion today to the evaluation of the ZCorp Z510 printer located in CSSE, UWA.
- Result of a ARC Linkage Infrastructure, Equipment and Facilities (LIEF) grant by M. Bennamoun et al. Titled "3D Scanning and Printing Facilities (3DSPF)"

## 3D model is "printed" slice by slice



Two representative slices





# Limitations / Specifications

- Only solids can be printed, must have an “inside” and be of finite thickness. This is a common problem with trying to print existing models with single polygon facets.
- The final models can be quite strong, after being infused with Supa-glue. The most likely cause of breakage is while extracting the model from the powder. Main limitation is on the thinnest structures that will survive extraction.
- Structures also need to be capable of being self supporting after being extracted and before infusion. One solution is to infuse parts of the model while it is being extracted but while still supported by the powder.
- Seems to be some colour fidelity issues, variation in colour depending on the orientation of the surface. [Still requires investigation to see whether it is inherent or an issue with the machine we have.]
- Maximum build dimensions: 250 x 350 x 200 mm.
- Maximum theoretical resolution: 600 x 540 dpi.
- Some models require a significant manual post processing stage.



Close to the minimum thickness ~ 4mm

## Standard tricks: infinitely thin surfaces

- Single polygonal faces are extruded to have a finite thickness.
- Can be preformed by most modelling software packages as well as in custom code.
- Extrude along each polygon normal or the average surface normal (example shown here).



2D textured mesh, no thickness



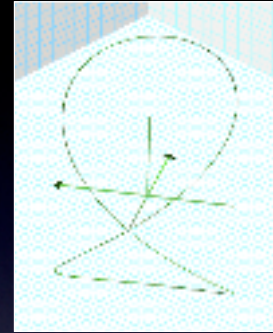
Extruded model ready for printing

## Standard tricks: lines and curves

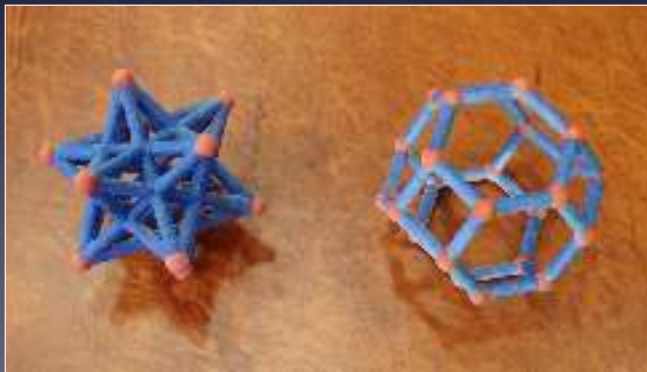
- Lines turned into cylinders of finite radius.  
- For example: for molecule bonds.
- Parametric circle sweep along a curve.



Polyhedra edges/nodes

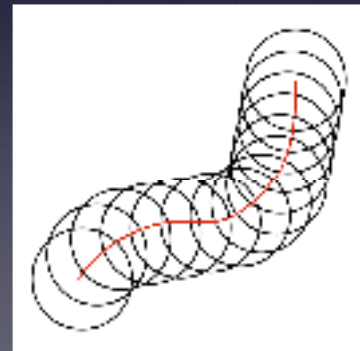
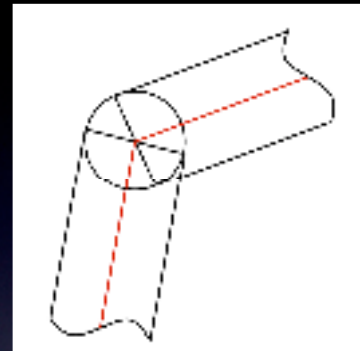


Box curve: circle sweep



## Standard tricks: lines and curves

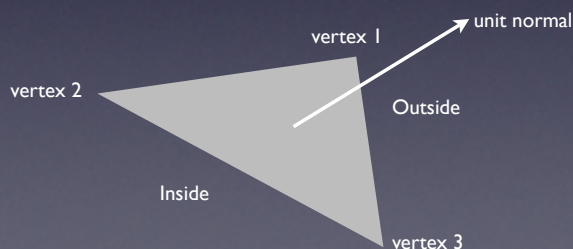
- Curves turned into lots of spheres or cylinder/sphere pairs.
- Former can add additional surface texture, the more spheres the smoother the result.
- Inefficient especially for STL (no sphere primitive) but often acceptable for VRML.





# File formats: STL

- STL: literally STereo Lithography
- Extremely simple to create
  - Defines nothing but triangles [3 vertex facets]
- Normal determines what is inside/outside (if provided), otherwise determined by vertex ordering.
- Assumes right hand coordinate system for cross product determination of the normal.
- Exists as a binary and ascii (human readable) format



## STL example

```
solid objectname
  facet normal -9.49 1.87 -2.51
    outer loop
      vertex -1.42 5.22 8.09
      vertex -1.78 3.37 8.09
      vertex -1.85 3.40 8.34
    endloop
  endfacet
  facet normal -9.49 1.87 -2.51
    outer loop
      vertex -1.85 3.40 8.34
      vertex -1.48 5.22 8.34
      vertex -1.42 5.22 8.09
    endloop
  endfacet
  :
  :
  :
endsolid
```

# File formats: VRML

- Virtual Reality Markup Language.
- Not specifically a rapid prototyping format but adopted as a standard 3D format by the industry.
- Also a text/human readable file.
- Required if colour is necessary, also supports texture, see earlier terrain model example.
- I can supply some standard functions for C to assist in data to VRML conversion.
 

```
WRLHeader();
WRLSphere();
WRLCone(); // Also for cylinders radius1=radius2
WRLFace();
```

## VRML example

```
#VRML V2.0 utf8
WorldInfo {
  title "Polyhedra"
  info [ "By Paul Bourke" ]
}
Transform {
  translation 0,0,1
  children [
    Shape {
      appearance Appearance {
        material Material {
          diffuseColor 1 0 0
        }
      }
      geometry Sphere {
        radius 0.103366
      }
    }
  ]
}
:
:
:
```

# Summary

- Rapid prototype hardware exists and is relatively affordable.
- There are clearly defined limits on what geometric forms can be created.
- The value of tactile visualisation for public outreach and education seems obvious.
- The value for researchers and peers is likely to depend on the application/discipline.
- If you have potential applications then using the facilities at CSSE is relatively painless.

# Examples



Knots, polyhedra, curves



Solution to Laplace equation in spherical coordinates

## Examples



Asteroids, Eros and the “dog bone”

## Example



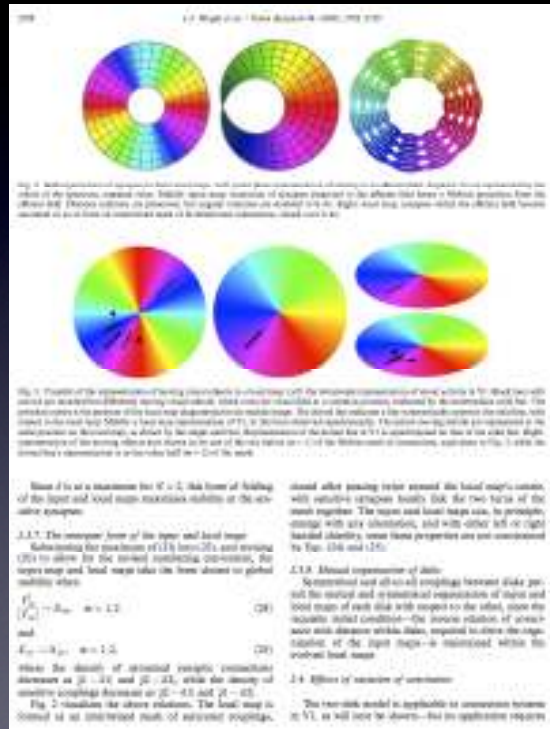
Geology / fossils



# Examples



Topology arising from research in human vision.



## Discussion ... Questions?