Presenting Scientific Visualisation Results as 3D Crystal Engravings.

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Abstract

Scientific visualisation traditionally concentrates on presenting data to our visual system. It generally employs generic digital displays but also often high end specialist hardware that more fully exploit characteristics of our visual system such as visual acuity, stereopsis, and peripheral vision. The other senses are often ignored. Although there are some instances of successful sonification (converting data directly to audio), sound is most often used to enhance the visual experience with an imprecise relationship to the data. Similarly various devices have been developed to allow one to feel datasets but haptics is more commonly used to enhance tactile interaction with objects within a virtual world.

It is often difficult to present datasets in a 3D format to both a lay audience or ones peers without access to the specialist hardware used in the laboratory. In an earlier exploration of these ideas datasets were "printed" as physical 3D models [1] using technology designed for rapid prototyping. This poster introduces some further investigation of a process that may be used to create physical models of data, in this case, namely 3D laser engraving into crystal block. While in this case the resulting physical objects do not permit the data to be felt directly, it does allow one to explore the 3D geometry with our hands in the same way as we explore other real world objects. The blocks of crystal are also well suited to presenting data to peers at conferences without the need for specialist hardware.

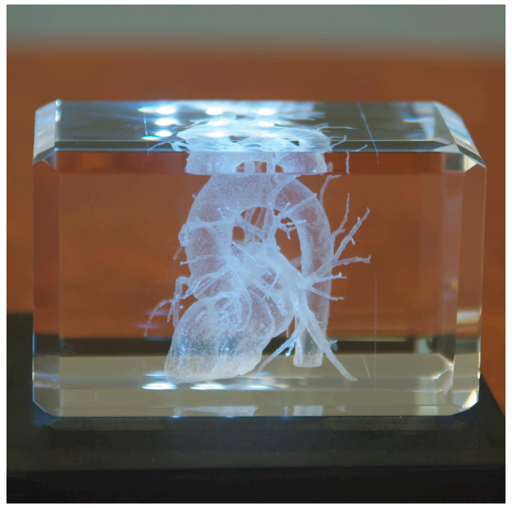

Figure 1. Human heart, point cloud derived by sampling an isosurface from the MRI volume.

Introduction

Crystal engraving employs a laser beam that can be focussed at a precise 3D position within a crystal block, the heat at this focal point causes a small crack or bubble to form. The accuracy at which these bubbles can be formed is very precise (in the order of tens of microns) and the diameter of the bubbles is typically tenths of a mm. The generic term for the process is Sub Surface Laser Engraving (SSLE) and it has been around since the 80's. A common application has been the creation of tourist trinkets and more recently companies offering 3D engravings of human faces derived from stereoscopic or structured light capture and subsequent 3D reconstruction [2].

Limitations

There are clearly some limitations inherent to the process that restrict it to certain types of data visualisation, some of these are obvious while others are unexpected.

1. It is clear that colour is not possible, the bubbles only appear as white dots due to scattering of any incident light.
2. The dots are of fixed size so that cannot be used directly to represent grey scale information. However the dot density can be varied within a region to convey a linear scale.
3. An initially unexpected constraint is an upper limit on the bubble density. Localised cracks will appear if the bubble density is too high, see figure 2.
4. If the point density is too low then the object appears too faint, see figure 3.

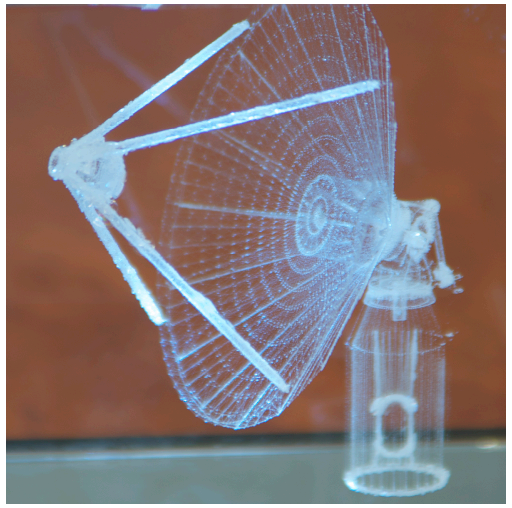

Figure 2. Example of localised cracking due to high bubble density along the 4 telescope support arms.

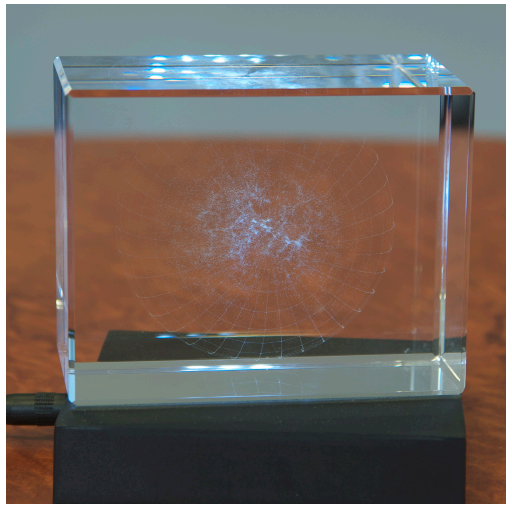

Figure 3. Example of insufficient points, each point represents a galaxy from the 6dF galaxy survey.

Data Generation

In the process of representing data in this way, algorithms have been developed that extract a suitable point cloud from various types of dataset, namely volumetric (figure 5) and polygonal (figure 6). In both cases the key is creating an appropriate density of dots, enough so that the surfaces are clearly visible and not too high such that cracking occurs.

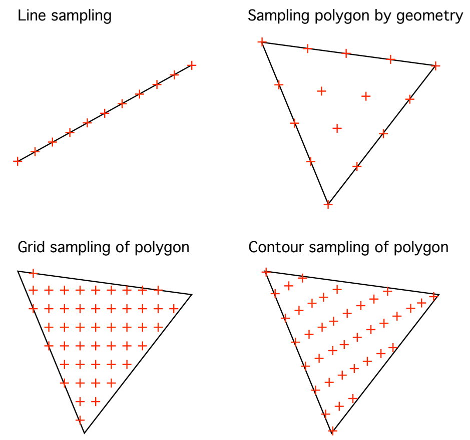

Figure 4. Various polygon sampling schemes.

Two approaches exist for creating suitable point clouds from volumetric data, the first is to create a point at positions in the volume if the voxel value that position lies within some range (figure 5). Another approach is to first create an isosurface using marching cubes say and then polygonise that polygon model (figure 1). The direct volume sampling is the easiest and works best when the resolution of the volumetric data is a reasonable match to the final point density in the crystal.

Figure 5. Mummy, isosurface at bone density from a CT scan of an Egyptian mummy.

A number of options exist for creating a point cloud from a polygonal dataset. Whichever one is used one generally needs to only add a point to the final point cloud if the point is at least some minimum distance from any other point. Candidate points can be acquired by considering the vertices, the center of vertices, sampling the edges, or even sampling the faces, see figure 4. The best method depends on the characteristics of the polygons within the model. For example, polygonal models derived from marching cubes tend to be approximately equal size and high density in which case sufficient point density may be achieved by simple considering the vertices themselves. For CAD based models there may be large polygons which will need their surfaces subsampled. Another approach is to contour the model along one or two axis planes and sample points along those contour lines.

Hardware and Data Format

The laser engraving machines are available from a number of suppliers, the machine used for this exploration is the LE-X1000 [3] from Laser Machine. It is capable of on average 1000 points per second where each point is on the order of 0.05mm diameter. It can support crystal blocks up to a maximum of 10cm cubed.

The software that actually drives the laser engraver is proprietary but a straightforward datafile format based upon the DXF file standard is provided as an import data format. The only DXF structure supported is the POINT so existing DXF files still need to be converted in order to be used. An example of the minimal structure of a suitable DXF file is as follows:

```
0
SECTION
2
ENTITIES
0
POINT
8
LAYER1
10
-29.2
20
-42.5
30
-252.0
[additional point data here]
0
ENDSEC
0
EOF
```

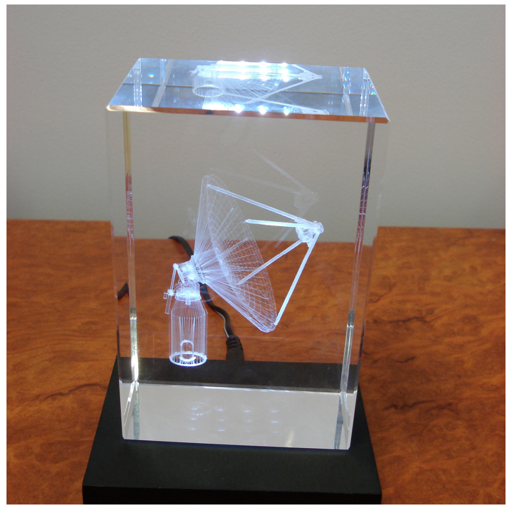

Figure 6. ASKAP telescope dish. Model supplied as an STL file that was subsequently sampled.

Conclusion

The process of creating optimal point clouds is now well understood and new datasets can be readily converted with a high probability of the engraving being a success. A number of researchers are now using these models to convey principles for teaching, to present in conjunction with poster presentations at conferences, and as research merchandise.

References

[1] Tactile Visualisation: Feel your data! WASP, UWA Seminar series April 2008. http://local.wasp.uwa.edu.au/~pbourke/papers/wasp08/

[2] Inner Crystal, Hillaries Boat Harbour, West Australia. http://www.innercrystal.com.au/

[3] 3D Laser Crystal Engraving System. http://www.3dlasermachine.com/