Exploiting our sense of touch for scientific visualisation

Paul Bourke
WASP, UWA

Introduction

Scientific visualisation can be described as the process of using computer graphics to improve the understanding of datasets and physical/ mathematical principles. The vast majority of the algorithms and techniques are designed to engage our visual sense. The human visual system employs two eyes to give us depth perception, hence the widespread use in visualisation centers of stereoscopic displays and more recently holographic techniques. Our visual system can also experience a wide peripheral field of view and this is exploited by immersive and virtual reality displays. And finally we have a high visual acuity and this has lead to the development of high resolution display technologies.

We have other senses that one might imagine could be exploited in the visualisation process. While our sense of smell is rather problematic due to imprecision and lack of techniques for its reproduction, attempts at utilising our sense of hearing are not unusual. The process of turning data into sound is called sonification and it can create very powerful experiences especially when used in conjunction with visual information. However it too is generally imprecise, there usually lacks a clear link to geometric data structures, and it is therefore only generally used to support visuals in a presentation or exhibition context.

Our sense of touch is much more precise and is ideally suited to data that can be directly mapped to geometric structures. We regularly use our tactile sense in our daily lives when exploring objects with our hands and as such one can easily imagine there could be benefits in using it for data visualisation. This is not necessarily a new concept, haptic devices that allow one to explore virtual objects/spaces while providing feedback have been around for some time. But haptic devices are a mediating device between the virtual geometric structure and the sense of touch. In the following discussion the interaction is not with virtual objects but rather objects that are created and experienced physically.

Rendering intricate geometries in tangible 3D form provides a more immediate experience and deeper insight than is possible through pictures and words alone. Carlo H. Séquin.

Rapid prototyping

Machines have been around for some years that can create physical models from a geometric description described by data on a computer. These have generally been found in engineering workshops [1] and are used for rapid prototyping, that is, allowing models to be created before manufacture without the need for the more time consuming process involving a human model maker. For a typical example of engineering visualisation see figure 1, a rapid prototype model of the proposed SKA telescope disk. Until fairly recently these machine have been relatively expensive to both buy and maintain but more importantly they have been limited by the types of geometries they could create. While these limits are acceptable in many engineering applications they severely restricted their use for the more general visualisation applications proposed here.

Figure 1: SKA (proposed) telescope dish (2007).

In 2000 ZCorp [2] first announced a new more affordable rapid prototyping process, it is this technology that will be explored here. The technique these machines used overcame many of the structural issues with the earlier rapid prototyping technologies and are significantly more cost effective. Both the earlier rapid prototyping technologies and the ZCorp approach create the model slice by slice vertically, the difference is the earlier machines employed a liquid polymer while the current machines use a powder. This key difference allows more convoluted models to be constructed since the model no longer needs to be self supporting during manufacture.

Examples

An example of a structure not ready formed by some of the earlier technologies is given in figure 2, this mathematical knot has portions that would not be self supporting during manufacture. In this case the realisation that if any one piece is removed then the other two will separate is much clearer when holding and exploring the physical structure [3].

The machine is essentially a fancy ink-jet printer that deposits a binding agent, rather that ink, on a bed of powder [4]. It was a straightforward extension of this process to create colour models by depositing a coloured binding agent, this was introduced in 2005 with the ZCorp Spectrum Z510 model. The support of colour is important for visualisation since colour is often used to represent variables additional to those mapped to geometry. In figure 3 a simple molecule has been created, in terms of visualisation one immediately notices a twist in the central structure that is not appreciated nearly as quickly when viewing this molecule on a computer display. The twist is revealed by simply placing the model on a flat surface.

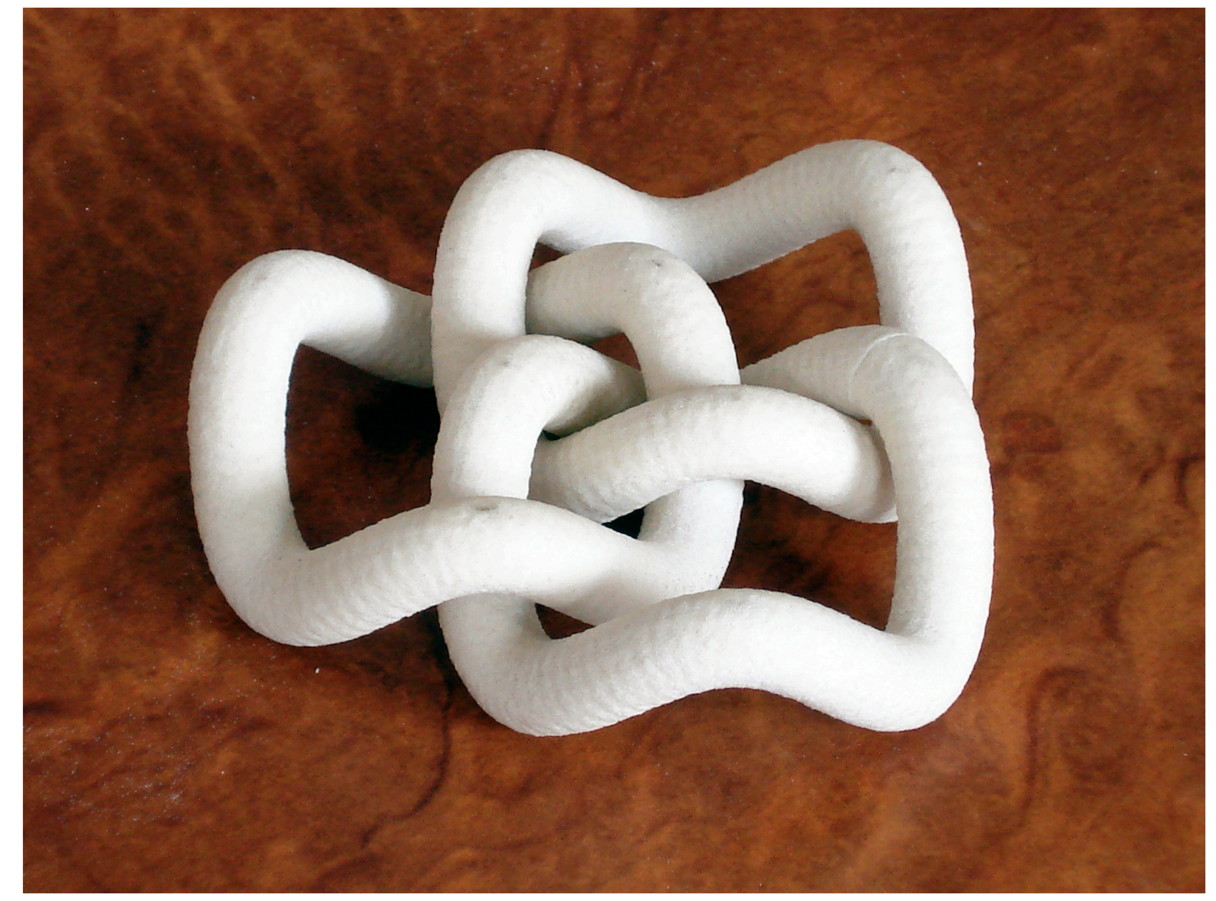

Figure 2: Mathematical knot.

Another opportunity this form of visualisation provides is the ability to present objects not normally accessible due to fragility or value. Figure 3 is an example of a fossil that has been digitally captured and then reconstructed to allow tactile exploration without causing damage to the original. In this case the powder texture of this process is particularly convincing because it gives the model a believable rock/limestone feel.

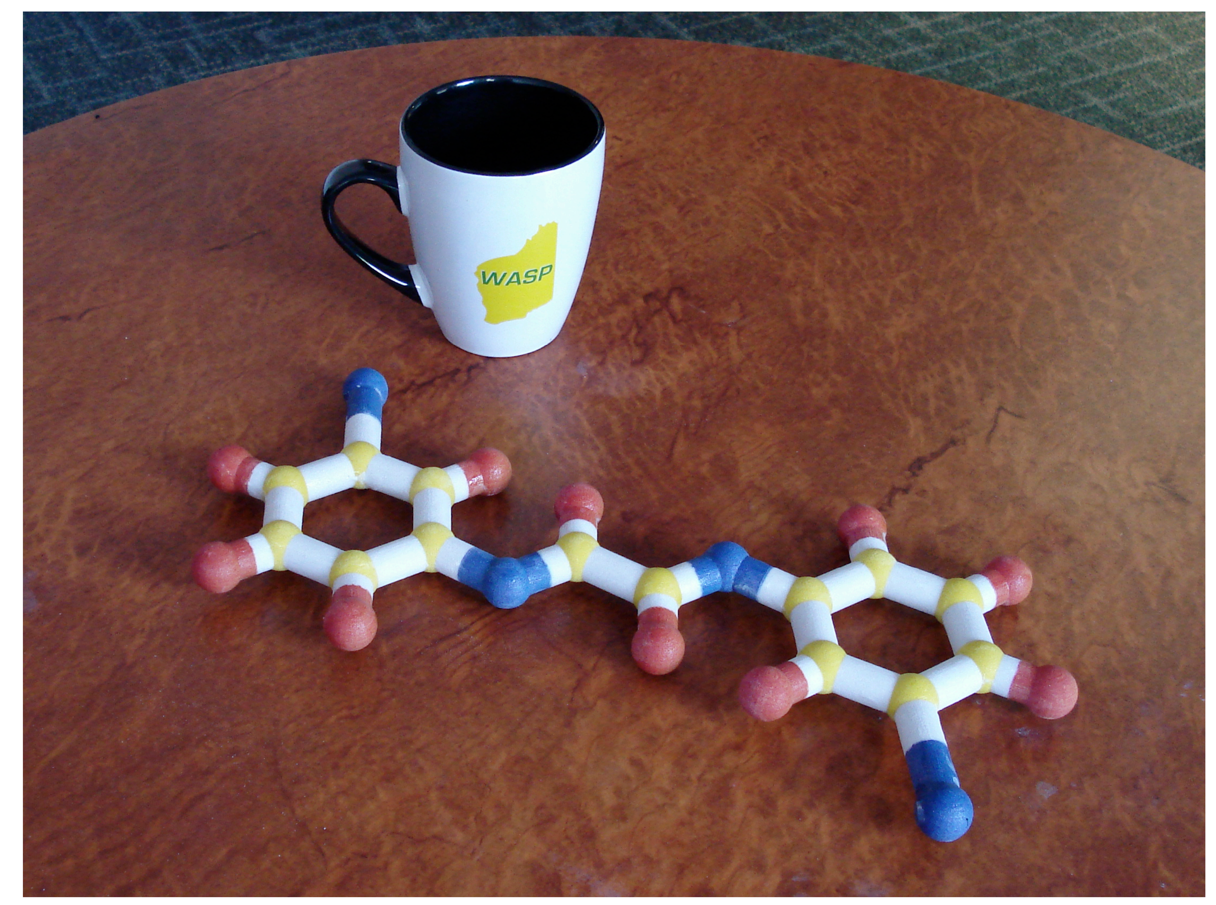

Figure 3: Molecule. Courtesy Joshua McKinnon.

There are still limitations [5] to the topologies these machine can create. The greatest limitation at the moment is the thinnest structures that can be formed and still survive being extracted from the vat of powder. There are compromise solutions, for example the knot in figure 2 was created not as a thin string but as thick piping. Similarly for surfaces it is necessary to perform some sort of thickening in order to create a structurally sound object. An example of this is shown in figure 5, the computer model is a single mesh (infinitely thin) but it is extruded in a favourable direction to form the closed solid object required for all rapid prototyping models.

Conclusion

The value of tactile visualisation [6] is clearly a useful option for those datasets that can be supported by the limitations of the current technology. It presents cues that cannot be experienced with purely digital display technologies. As such it seems appropriate for it to be another tool available when one is choosing how to visualise data [7] for both the researchers, their peers, and for presentation to the wider community.

Figure 4: Fossil.

Acknowledgement: The models created here were formed on a ZCorp Spectrum Z510 within the Computer Science Department, UWA [8].

Figure 5: Cliff. Courtesy Klaus Gessner, Hagen Deckert.

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