Improving Insight in Medical Volume Rendering

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Extended Abstract

Volume rendering is now a well established technique for the display of three-dimensional volumetric data. The fundamental idea is to model the dataset as a heterogeneous gel-like material whose colour and opacity at any point is determined by a mapping, or transfer function, of the data value. The gel is then rendered using computer graphics techniques such as ray casting.

The technique has had some success in medical visualization although it remains quite common for clinicians to prefer sequences of 2D images. This challenge has spurred the visualization community to seek improvements to the basic volume rendering technique, and some of these improvements will be discussed in the talk.

A difficulty until recently has been the speed at which volume rendered images can be created. Ray casting using CPU technology is slow and does not allow real-time interaction by changing the viewing direction for example. This has dramatically changed in the last few years with the advent of GPU technology. The data can be stored as a 3D texture and fast GPU-based texture rendering now allows interactive volume rendering on commodity hardware. An excellent overview of this area is provided by the IEEE Visualization tutorial [1].

The improved hardware performance has been accompanied by an investigation of new algorithmic techniques. Much of this comes from study of traditional medical illustration, where special effects are used to enhance the communication of important detail. Rather than try to reproduce reality, medical illustrators focus on a more abstract approach this can be traced back to Leonardo da Vinci who used exploded views to illustrate a baby in a womb.

Thus illustrative volume rendering has become an important research topic. It has been explored from two directions: geometric effects, where the picture is distorted to highlight some area, or feature, of interest; and rendering effects, where effectively the colour and opacity of the gel is modified in order to highlight some particular features. In fact most of the ideas combine elements of each approach. A simple but vital geometric effect is an ability to clip away parts of the volume that are not of interest.

The talk will review these algorithmic developments in general. Pioneering work on rendering effects was carried out by Rheingans and Ebert [2], where they showed that non-photorealistic effects such as silhouette enhancement can increase our ability to comprehend medical image data. Again an excellent starting point for study in this area is an IEEE Visualization tutorial [3]. An important recent paper is by Bruckner et al [4] where the opacity is modulated so as to make important regions more opaque, and less important more transparent.

For a study of geometric effects we look in detail at one particular piece of work by ourselves at Leeds. This adopts the focus and context principle first put forward for two-dimensional presentation in information visualization. The idea is simple: often there is some area within the image that one wants to explore in detail, but by zooming in we lose the overall picture. In focus and context, we enlarge the focus region but retain a reduced size surrounding region to maintain context. This idea transfers quite readily to 3D, and has been found useful in the visualization of cerebral aneurysms from CTA data. A box can be defined around the aneurysm as the focus, and the data distorted so as to enlarge the box area and compress the remainder. Three styles of distortion can be applied: bifocal (as just described); fish-eye, where there is a continuous decrease in magnification from a specified focus point; and a volume lens, simulating a magnifying glass, where the focus region is magnified, the surrounding area is left unchanged, and there is a steep transition between the two.

This work is fundamentally a geometric approach. However it is enhanced by a number of rendering effects, such as modifying the opacity of a voxel according to its position relative to the focus region, or its relation to the viewing direction. Another useful effect is to highlight the focus region by colorisation. An evaluation by the neurosurgery team at Leeds General Infirmary was very positive perhaps surprisingly the geometric distortion did not cause any concern to the surgeons (although an interventional radiologist was less enthusiastic about this aspect).

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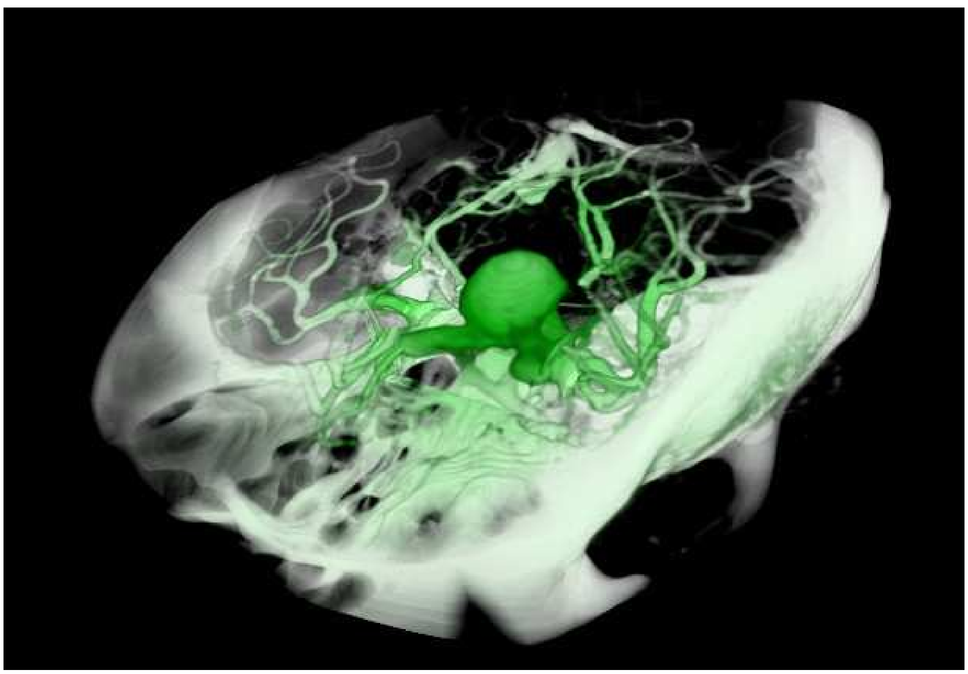

Figure 1. Focus and context visualization of a cerebral aneurysm

A key feature of the work is its careful exploitation of the GPU. The distortion is calculated by the CPU but stored as a texture and then used by the GPU in rendering. The figure shows an example of the work. Full details are in Marcelo Cohen's thesis [5]

References

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