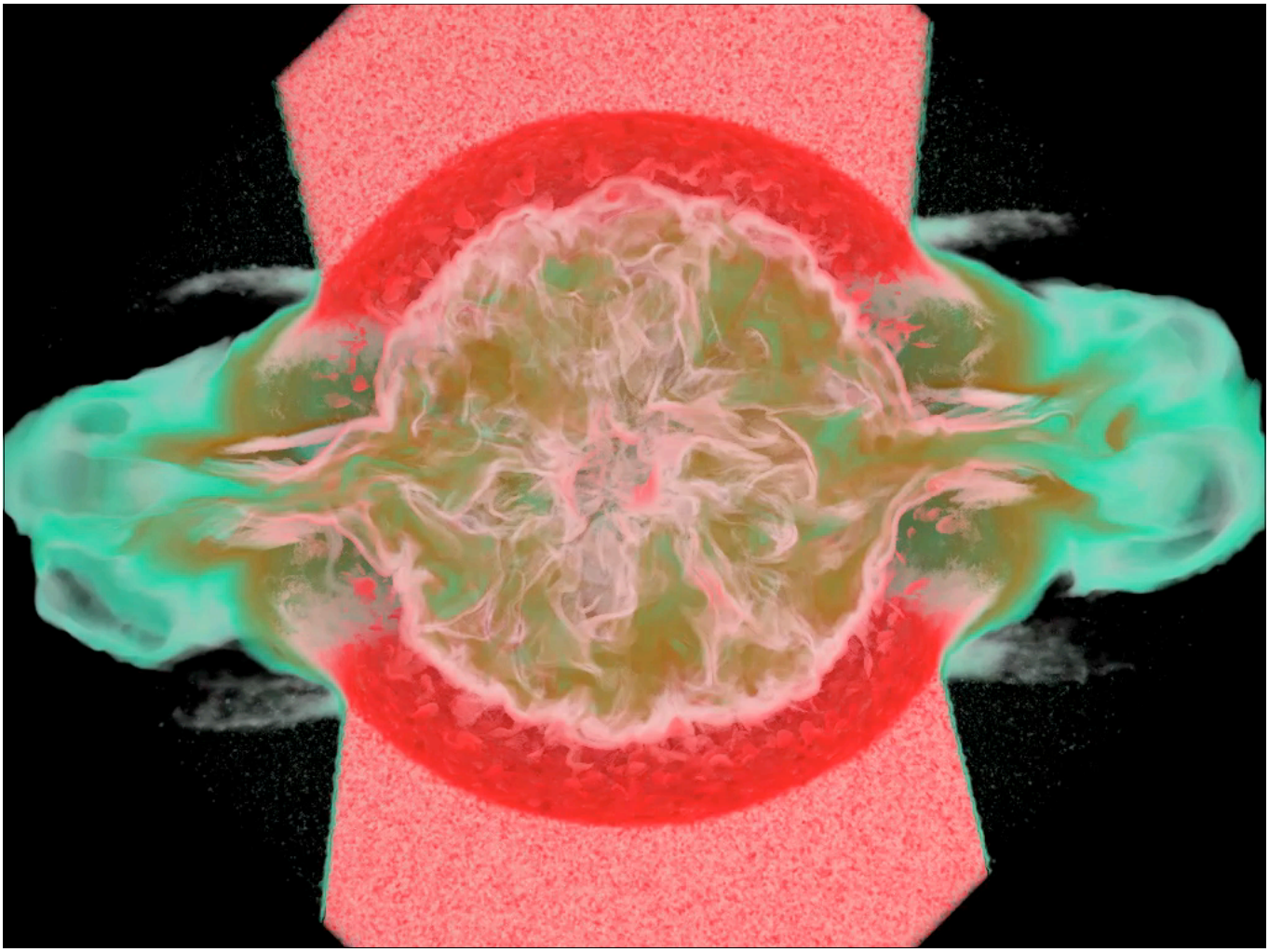
Volume Visualisation

Potential applications for educational content creation

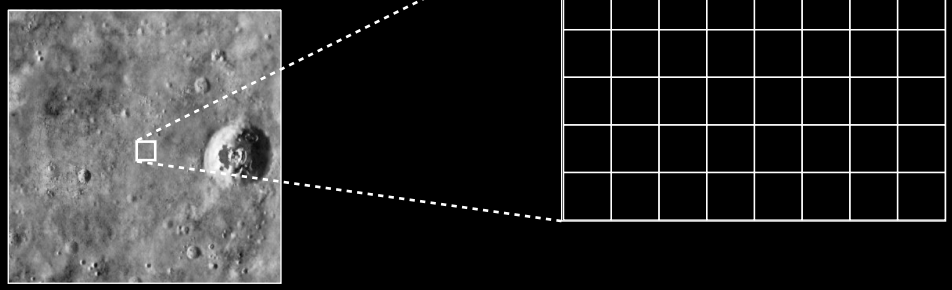
Paul Bourke
WASP / iVEC (University of Western Australia)

- Generation of 3D content directly from data rather than by 3D modelling.
- Realtime interactive exploration of 3D data by students.

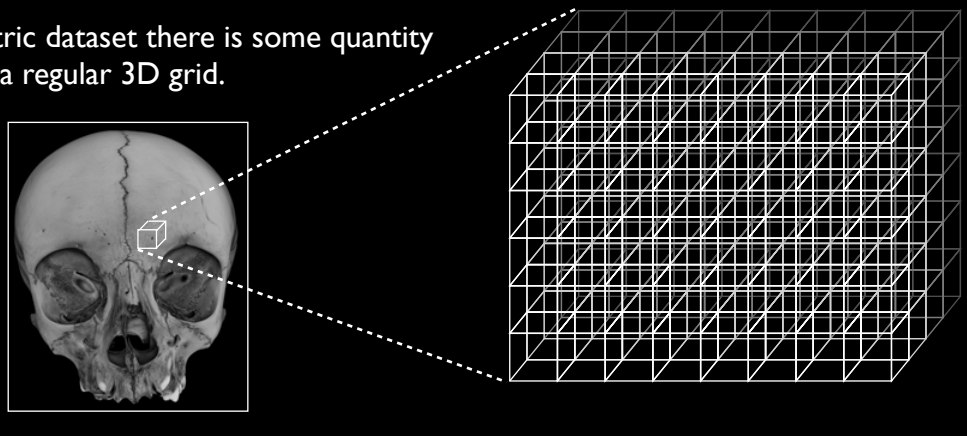


What is a volumetric dataset?

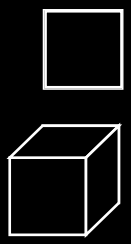
- A digital image contains some quantity sampled on a regular grid on a 2D plane.



- In a volumetric dataset there is some quantity sampled on a regular 3D grid.



Terminology

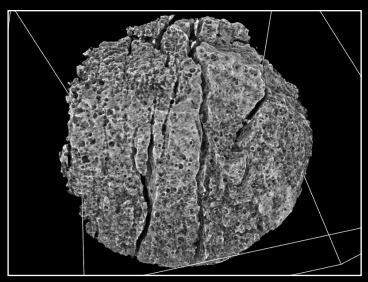


- In a 2D image the fundamental unit of measure is a "pixel".
  The quantity represented by the image is sampled at each pixel.
- In a volumetric dataset the fundamental unit of measure is a "voxel" (VOlume piXEL).
  The quantity represented by the volume is sampled at each voxel.
- The resolution of a 2D image is defined as the number of pixels horizontally and vertically. The resolution of a volumetric dataset is defined as the number of voxels in width, height, and depth.
- Image pixels are usually but not always square, likewise voxels are often but not always cubic. Note that some volumetric data can have variable voxel sizes.
- Depends on who you talk to and their area of research but generally
  - A "small" volumetric dataset may be < 200 voxels on each side.
  - A volumetric dataset may be considered "large" if it is > 1000 pixels on each side.
- Another important characteristic is the dynamic range of the data at each voxel. Most commonly a single byte, integer (2 or 4 bytes), or floating point. May even be vectors, multivariate, and so on.

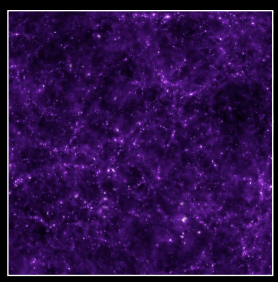
Volumetric data in research

- Volumetric datasets have been a common data type in many areas of science for some time.
- Traditionally one thinks about medical data, for example MRI.
- Other scanning and 3D imaging technologies include CT (MicroCT) and CAT scans.
  There are many others.
- Volumetric data also arises from numerical simulations.
  Quite common in astronomy and engineering (finite element calculations).
- In scanned volumetric datasets the quantity per voxel depends on the scanning technology. For example: MRI essentially gives water content, CT gives density.
- For volumetric datasets derived from simulation there can be multiple variables per voxel.

Medical research (MRI)



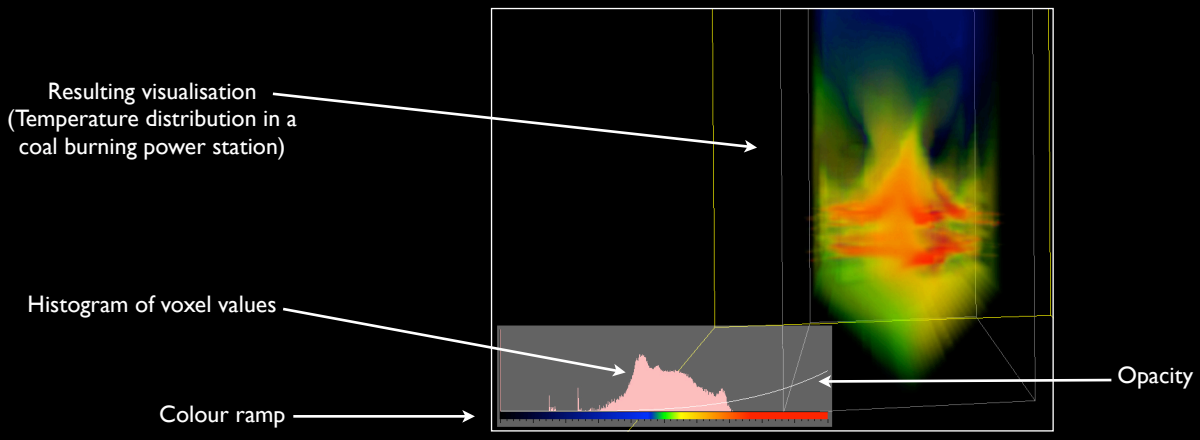
Geology (CT)



Physics (Simulation)

What is volume visualisation?

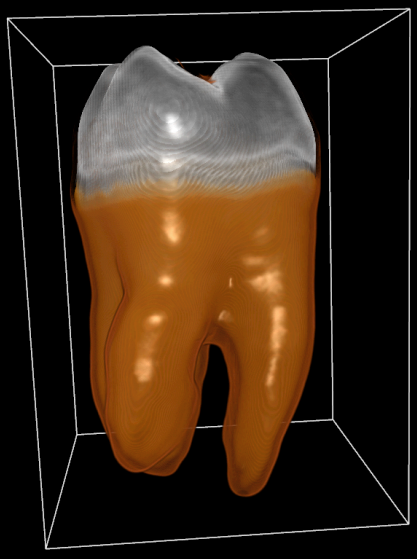
- The process of exploring and revealing the structure/interior of a volumetric dataset.
- The general approach involves a mapping between voxel values and colour/opacity.

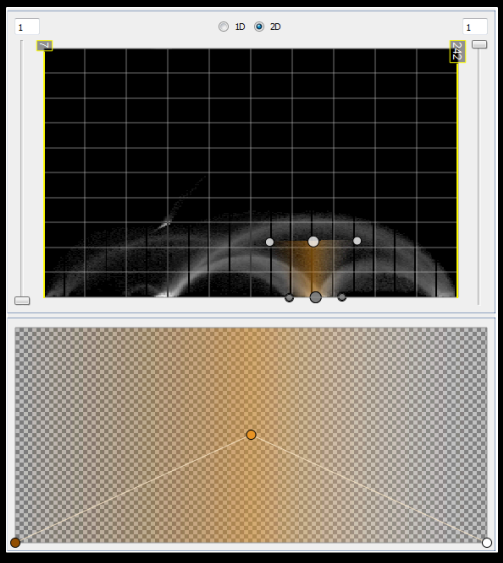


- Today most volume visualisation that runs in realtime is performed on the graphics card.
- The limit on the volumetric resolution for realtime performance is generally the amount of memory on the graphics card.

Live example: Tooth

- Enamel vs dentine, two different densities.
- Pulp within dentine.
- Boundary between enamel and dentine.



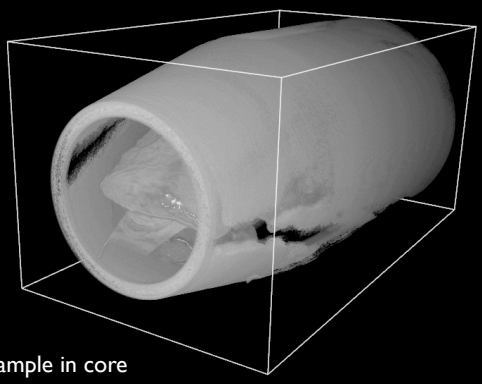


[Data: Tooth, sample0]

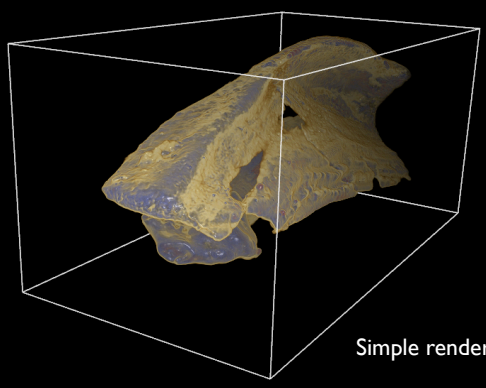
Challenges

- Volume rendering has always been challenging to perform in realtime.
- As graphics performance has increased so has the resolution of the data being generated.
  - The resolution of scanners is improving.
  - The resolution of simulations is improving with increasing high performance computing.
- The performance and storage demands increase with the cube of the volume size.
  eg: doubling the resolution on all axes is 8 times more demanding.
  - 256x256x256 volume at 2 bytes per voxel is 32MB.
  - 512x512x512 volume at 2 bytes per voxel is 256MB.
  - 1Kx1Kx1K volume at 2 bytes per voxel is 2GB.
- Identifying the different voxel ranges and the structures they refer to.
  Often straightforward, often difficult if two structures have similar characteristics.

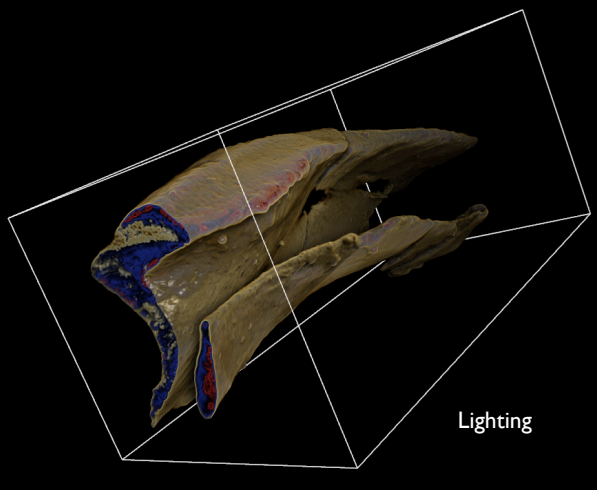
Live example: Jaw from Remigolepis



Sample in core



Simple rendering

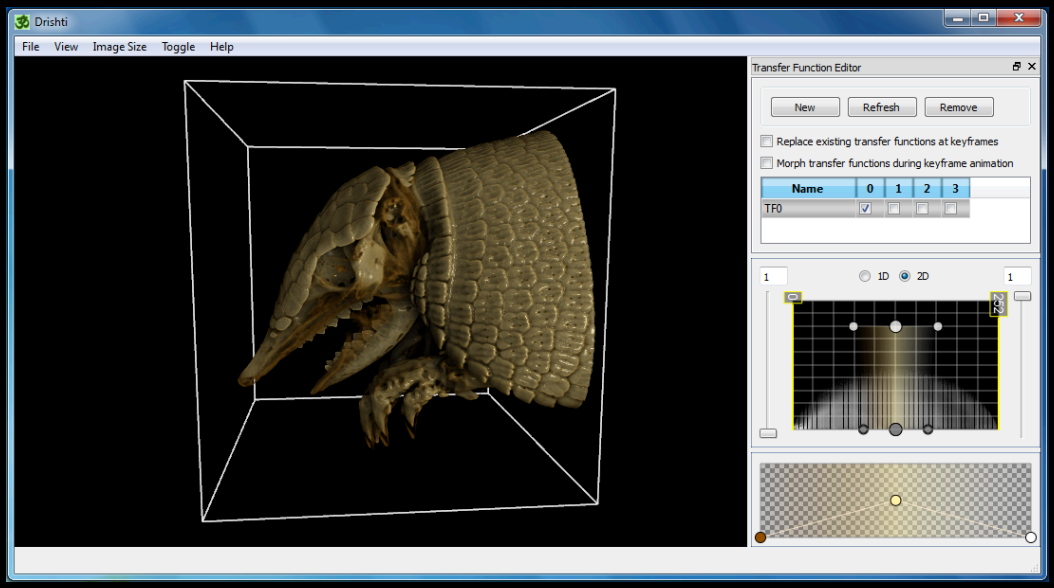


Lighting

[Data: Gill teeth, sample0]

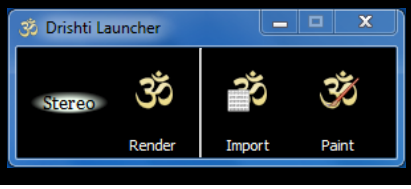
Drishti

- Drishti stands for vision or insight in Sanskrit, an Indian language.
- Developed by Ajay Limaye at the ANU (Australia National University).
- Available for MSWindows, Macintosh, and some Linux flavours.
  Also available as source code.



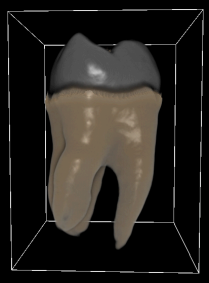
Important features

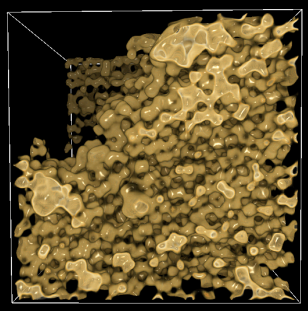
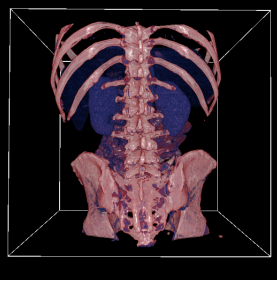
- All rendering performed on the GPU.
- 2 dimensional transfer functions: uses both the gradient and the voxel value in the shading model.
- Enables diffuse / specular shading and shadows.
- Consists of two main programs, a data importer and the render.
- Importer supports various commonly found volumetric file formats, resampling volumes, cropping, and filtering.
- Powerful keyframe based animation of (almost) all rendering and camera controls.
- Arbitrary clipping planes.
- A number of ways to tradeoff quality for interactive performance.
- Able to combine / superimpose up to 4 volumes.



Live demos

- Simple example to illustrate transfer functions: human tooth.
- Stag Beetle.
  Example of clipping planes.
- Cochlear.
  Demonstrate lighting.
- Reticulite.
  Example of animation.
- Human torso.



Final comments

- There are a large number of volumetric datasets being created in the sciences.
- CMCA (Centre for Microscopy, Characterisation, and Analysis) at UWA has a number of instruments capable of 3D scanning.
- Geology researchers (eg: Florian Fussies, UWA) are generating large volume datasets for their research into porosity and rock deformation, mostly using the Chicago synchrotron.
- Researchers across Australian Universities use the CT and MicroCT scanners housed at the ANU, the beam lines on the Monash synchroton, and other facilities.
- Researchers at ICRAR are regularly creating volumetric data from simulations, for example: cosmology and supernova simulations (recent iVEC intern student projects).
- Summary:
  1) In many cases volumetric data may already exist that can be used in the creation of teaching material .... if the data does exist then it is usually much more efficient to use that rather than engage in 3D modelling.
  2) While there can be benefits in creating simplified models for illustrating principles, these visualisations are based on real objects/data that can be explored in more engaging ways and sometimes with unanticipated discoveries.

Questions or comments?