Visualisation : Course Review

Visualisation – Lecture 18

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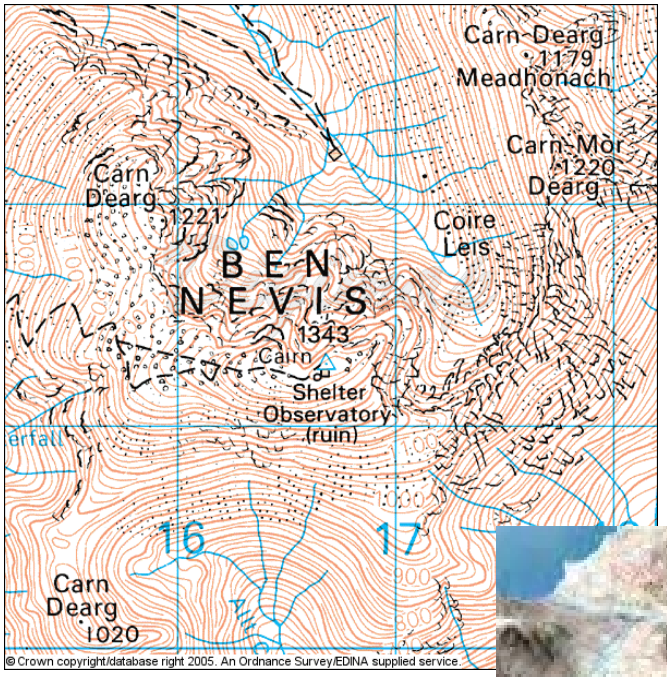
The Science of Visualisation

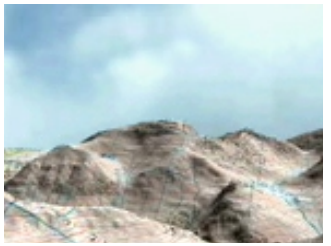
- **Conversion of numbers → images**
  - people are :
    - **poor at raw numerical data analysis**
    - **good at robust analysis of visual stimuli**

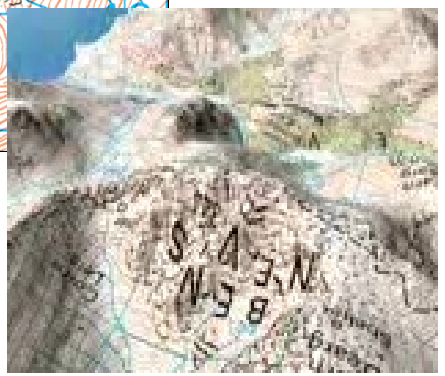
  → *convert numerical analysis into visual analysis*

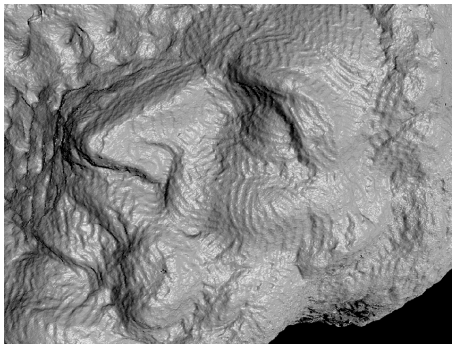
Why do we need visualisation?

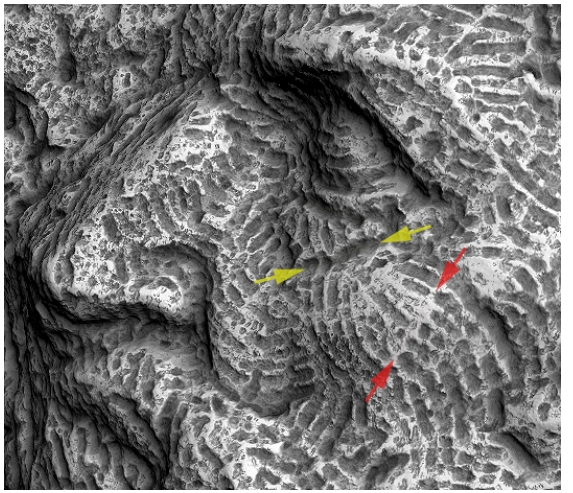


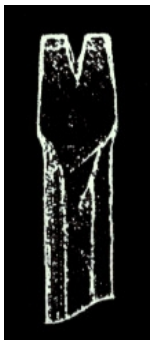
Ben Nevis Fly Through:
http://www.ordnancesurvey.co.uk







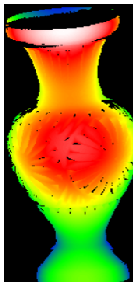
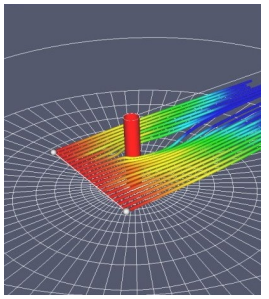




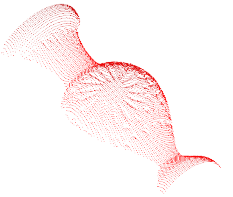
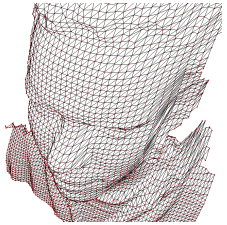
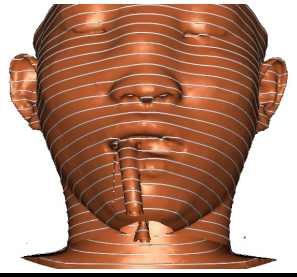
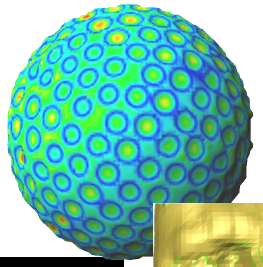
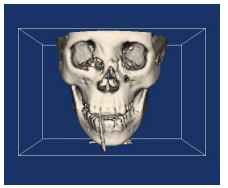
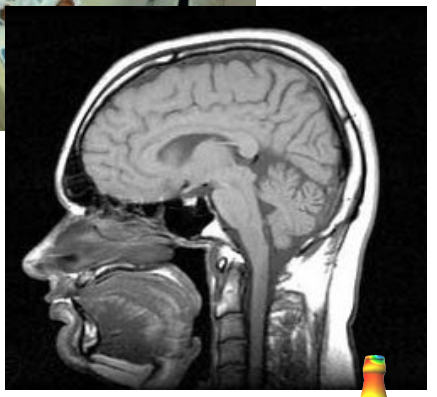
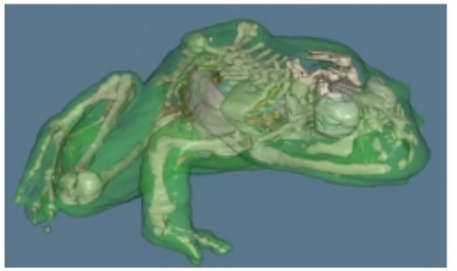
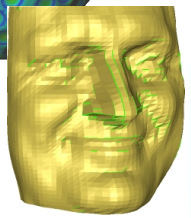
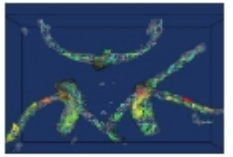
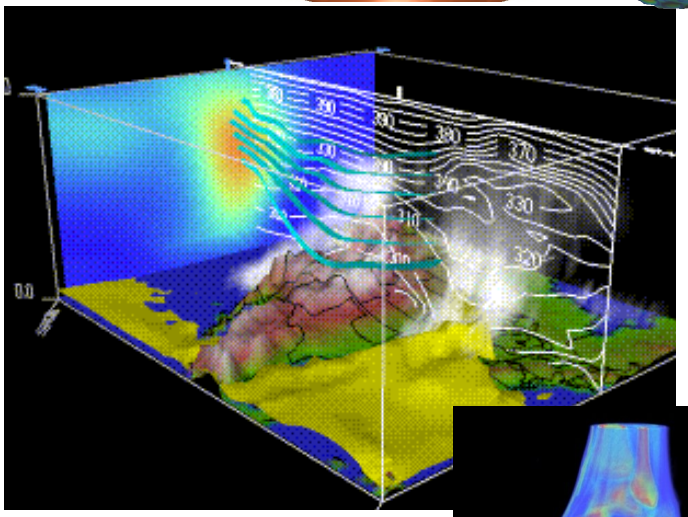
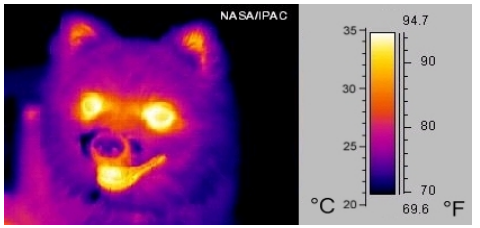
Stanford's *Digital Michaelangelo* Project http://graphics.stanford.edu/projects/mich/

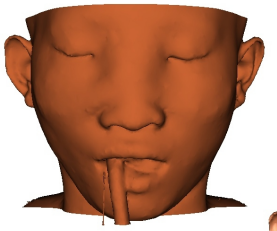
- The **extraction of *knowledge* from numbers**
- **Graphically exploring numbers** in order to **gain understanding and new knowledge - *interaction***

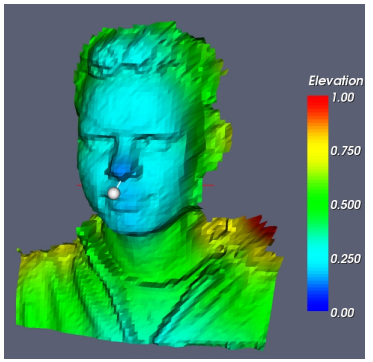
Visualisation Problems

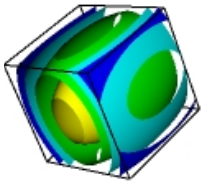
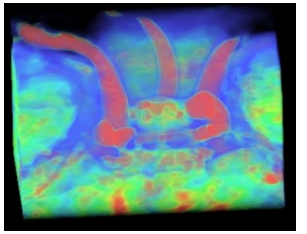
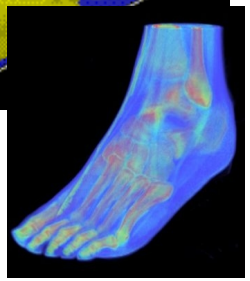
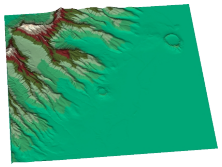
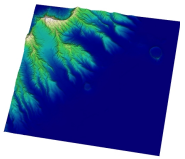
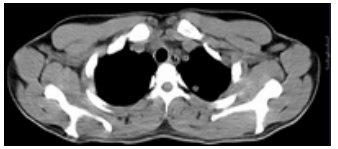
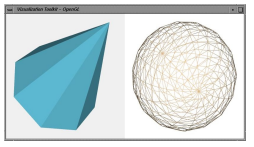
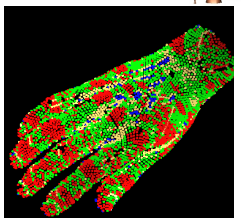
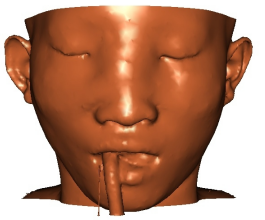










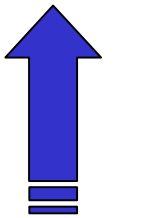











The visualisation process

- the effective presentation of knowledge

Knowledge
(Scientific papers, business strategy, a medical diagnosis etc).

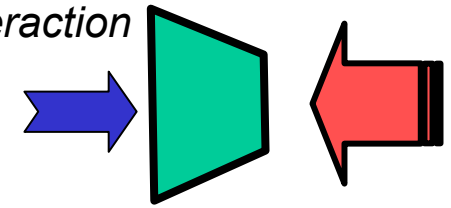
Observations
(could be scientific, medical or business sales figures etc).



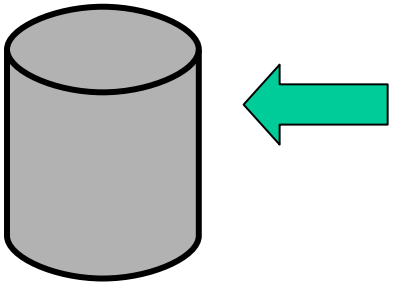
Visualisation algorithms

Human 'expert'

Interaction

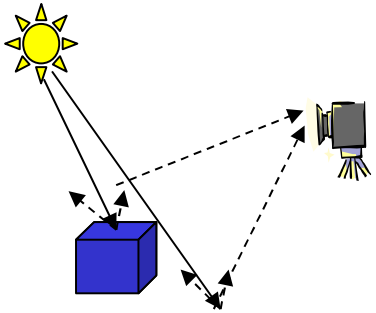


3D Computer Graphics

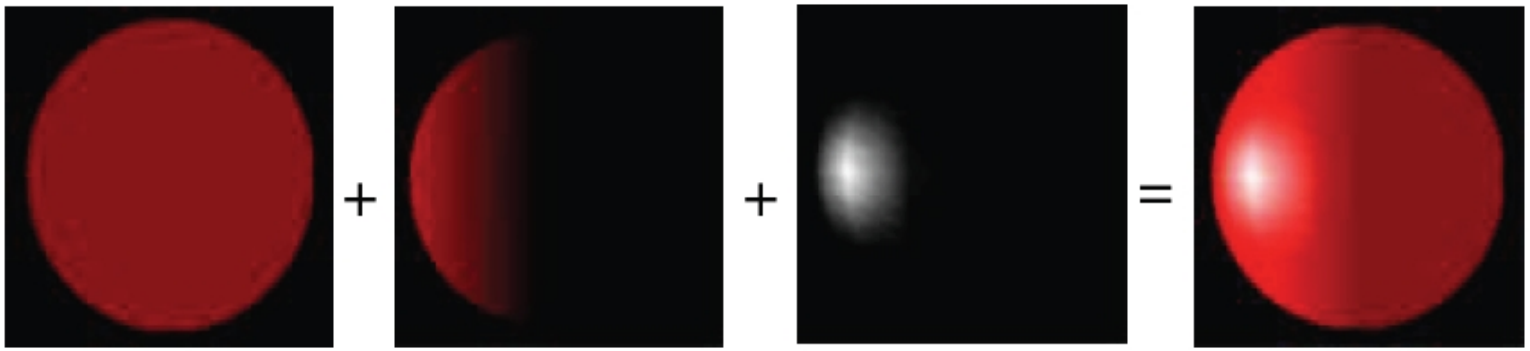


Numbers

3D Computer Graphics

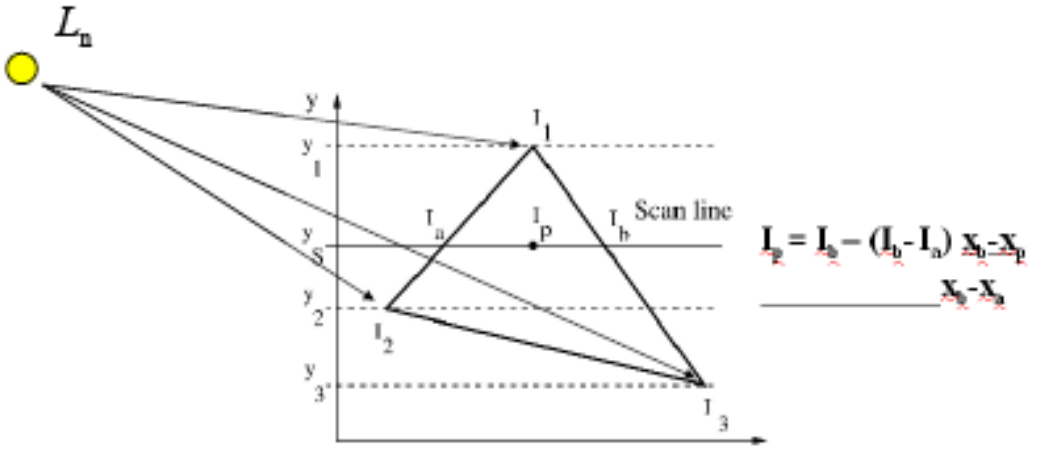


- our **primary tool** in computer based visualisation
- object **representation** : polygon surface meshes
- object **illumination : ambient, diffuse, specular**
- **camera model :** world to display transformation

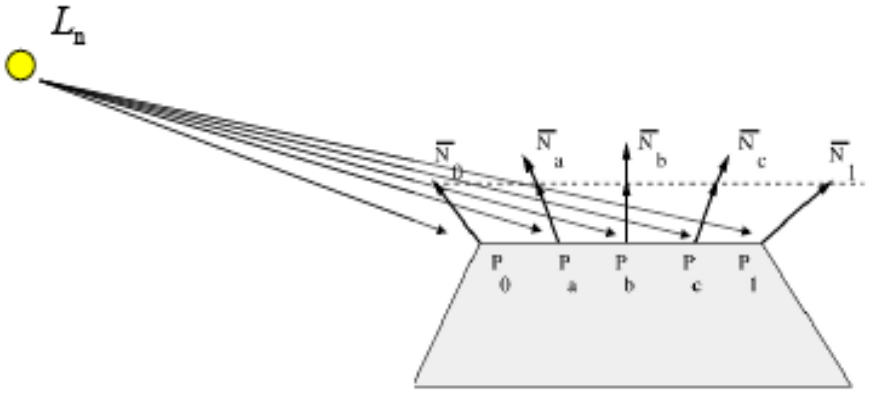


Ambient (colour) + Diffuse (directional) + Specular (highlights) = R_c

Gouraud & Phong Shading



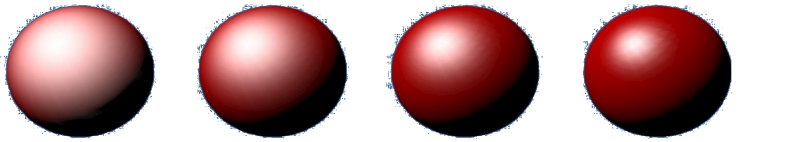
Gouraud shading model



Phong shading model

Graphics

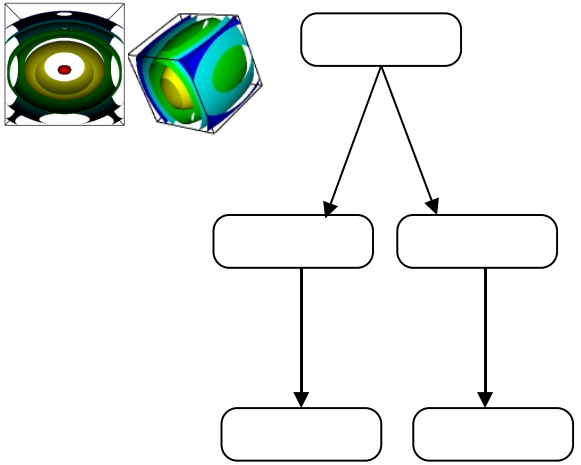
- Various factors that change the appearance



sp=4 *sp=100*

Visualisation Systems

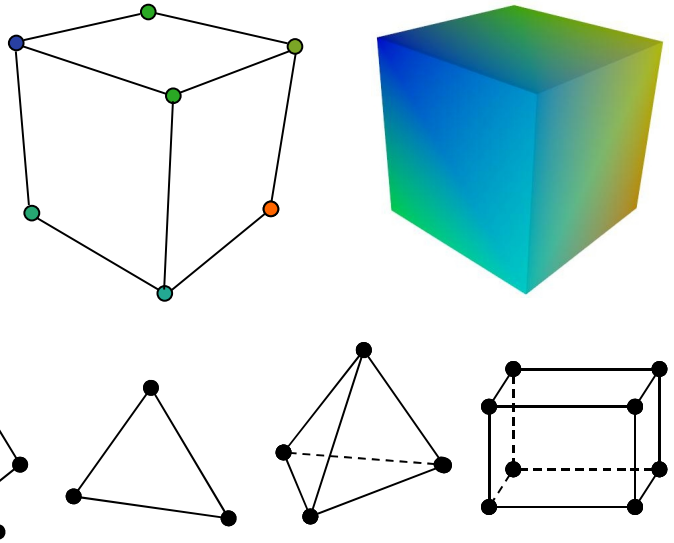
- **Visualisation Pipeline**
  - **data** objects**, process** objects**,** data **flow**
  - **design:** *connectivity, execution control, memory models*



Data Representation - Basics

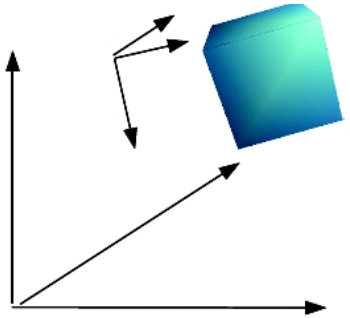
In order *to* ***visualise*** *we have to* ***represent*** *:*

- *Remember :* ***data is discrete***
  - *use* ***interpolation*** *over* ***topology***
- ***Data has.....***
  - ***topological dimension***
  - ***structure*** *&* ***value***
    - ***structure = topology*** *&* ***geometry***
    - ***value*** *= attribute data*
  - ***Topology & Geometry***

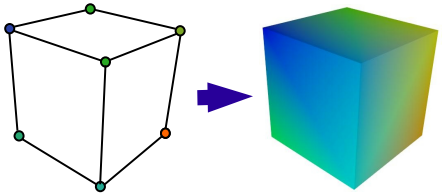


Data Representation - Advanced

- Global & Local Co-ordinates
  - Local: topological & parametric co-ordinates
  - transforms

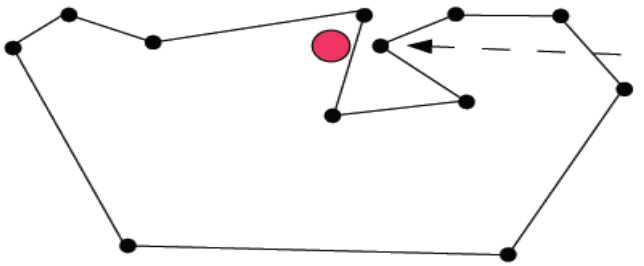


- Interpolation :



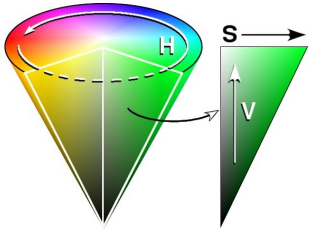
$$d = \sum_{i=0}^{n-1} W_{i.} d_i$$

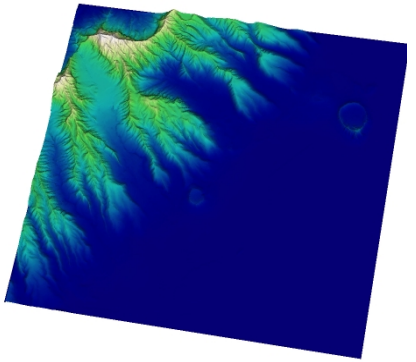
  - **Interpolate** the value **attribute data over a cell** by **weighted sum** of **attribute data at discrete cell points**
  - **How to do the interpolation for complex shapes?**

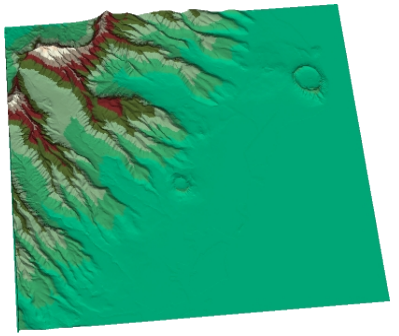


Scalar Visualisation

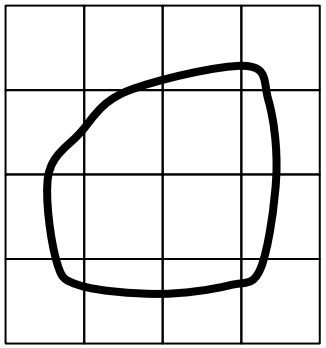
- **Scalar data : single value** at each location
- **Colour Mapping**
  - HSV colour space
  - LUT or transfer function

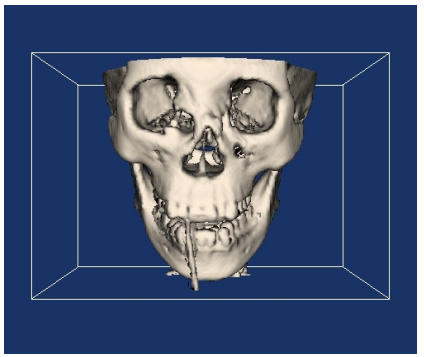


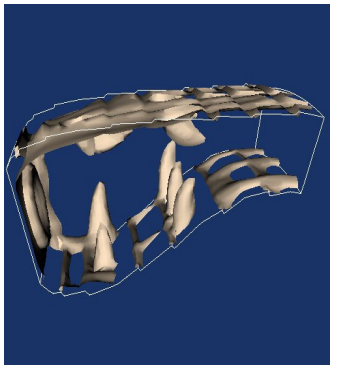




- **Contouring**
  - Marching Squares (2D), **Marching Cubes** (3D)



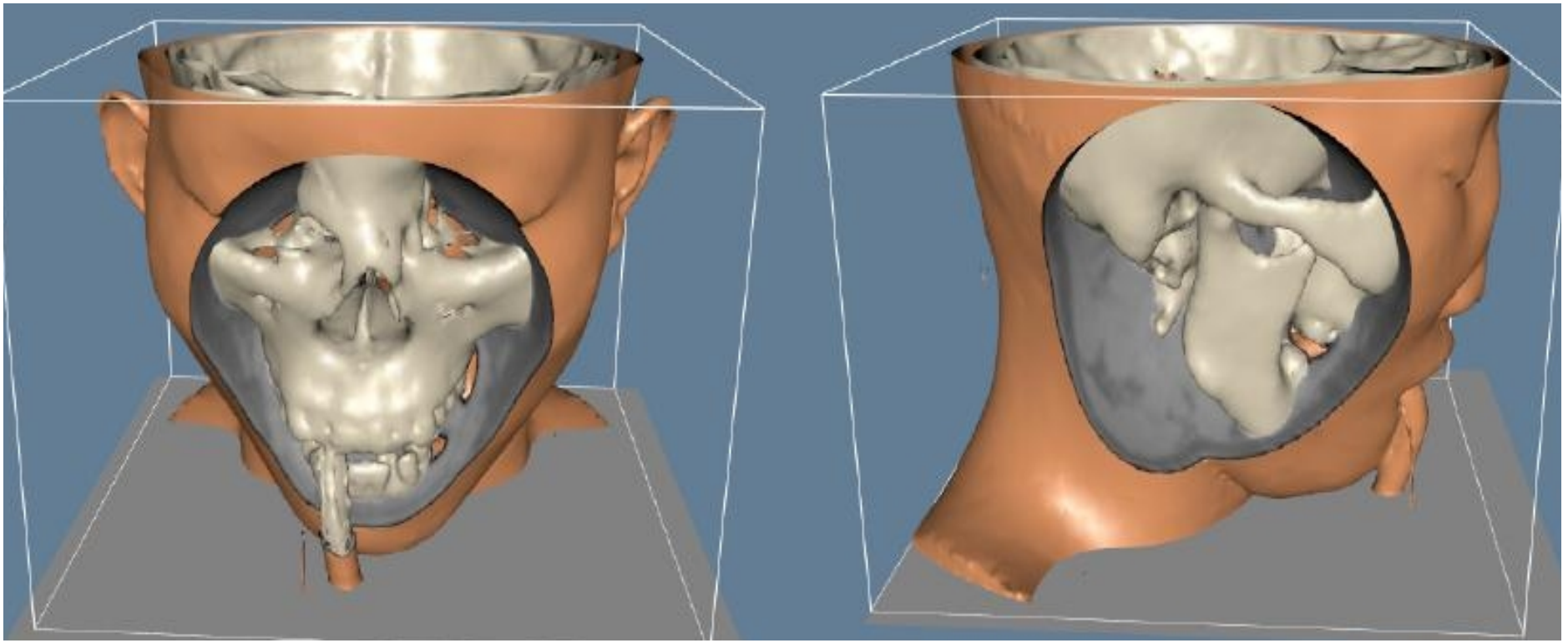




Scalar Visualisation - Example

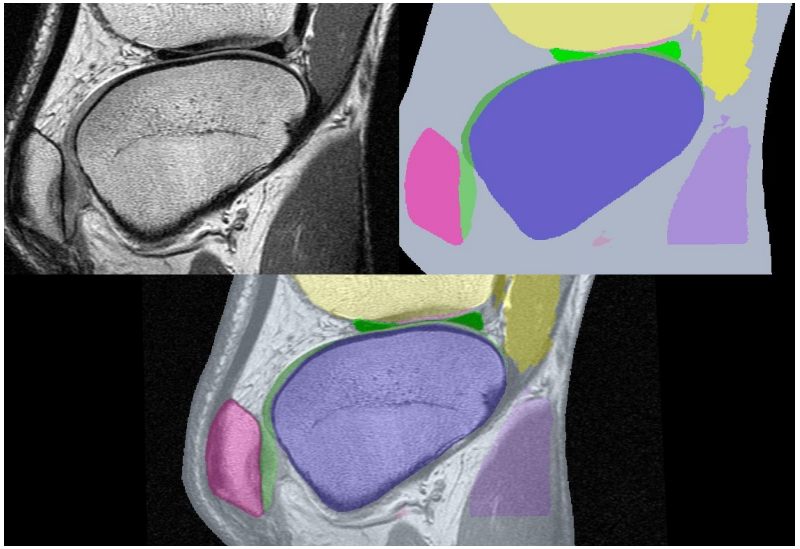
- Combing **contouring** (Marching Cubes)
  with **colour mapping** (skin/bones tones)

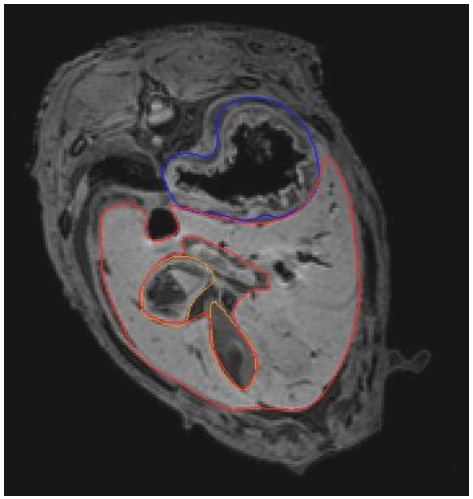
(from CT scanner, scalar = density)

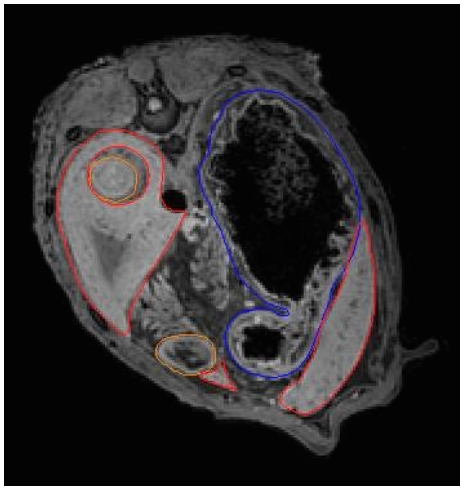


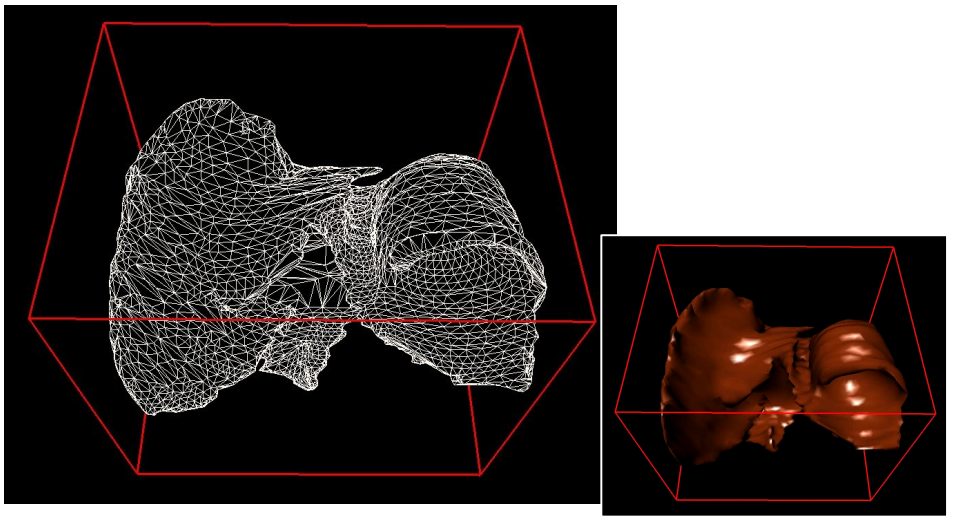
Contouring with MRI

- MRI data is different ....
  - requires image processing to extract structures
  - use NAUGES algorithm to reconstruct surfaces



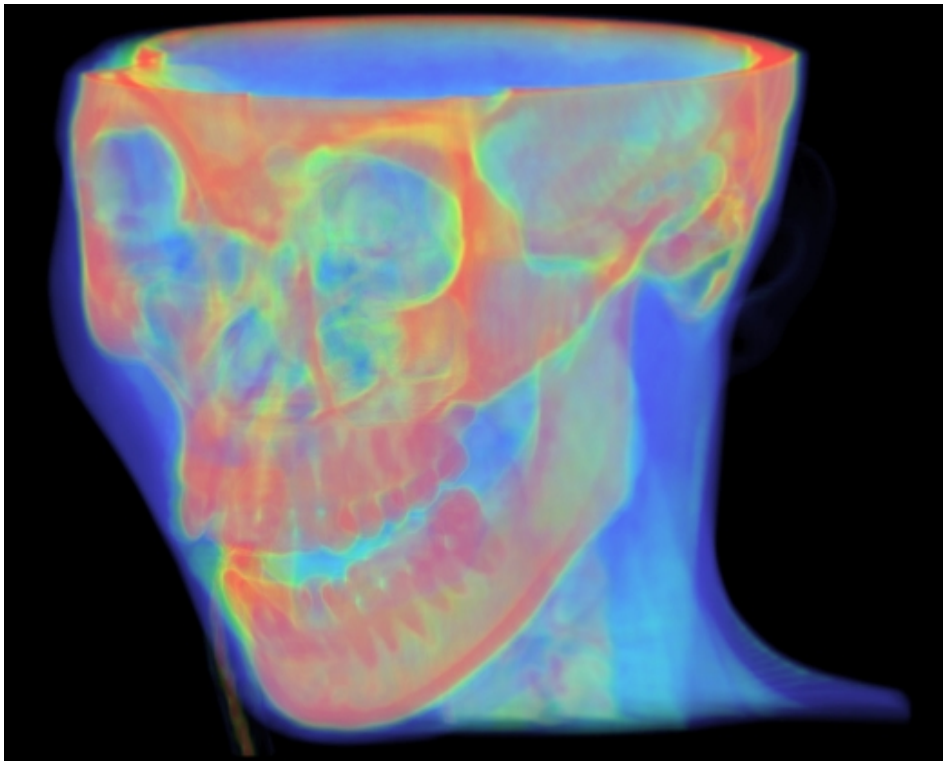


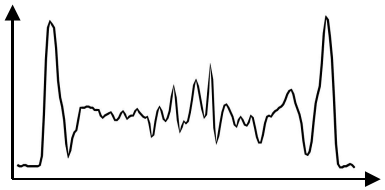


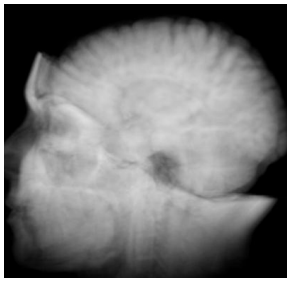


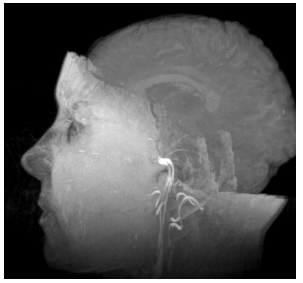
Volume Visualisation

- Alternatively we can use **volume rendering**....
  - **scalar volumetric data**
  - render using **transparency**
  - **Image Order** Volume Rendering
    - **Composite Intensity Projection (CIP)**
    - **Maximum Intensity Projection (MIP)** intensity transfer functions
    - What is the advantage of each method?
    - **ray casting** with **opacity**





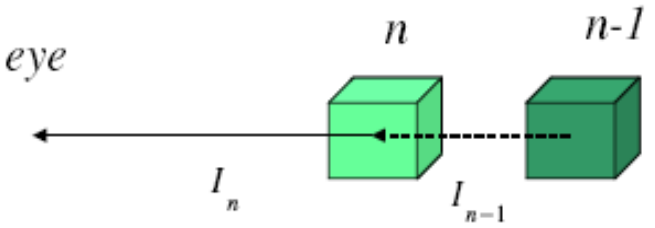




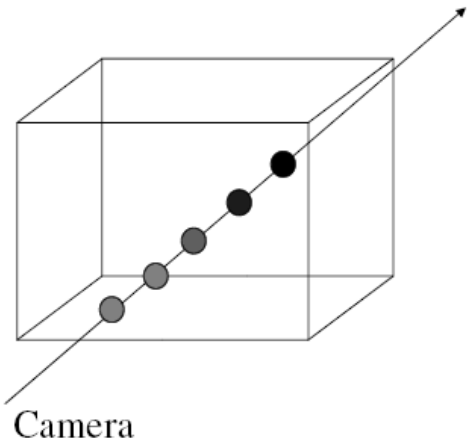
Rendering with Transparency

- Back-to-front ray casting

$$I_n = A_n E_n + (1 - A_n) I_{n-1}$$



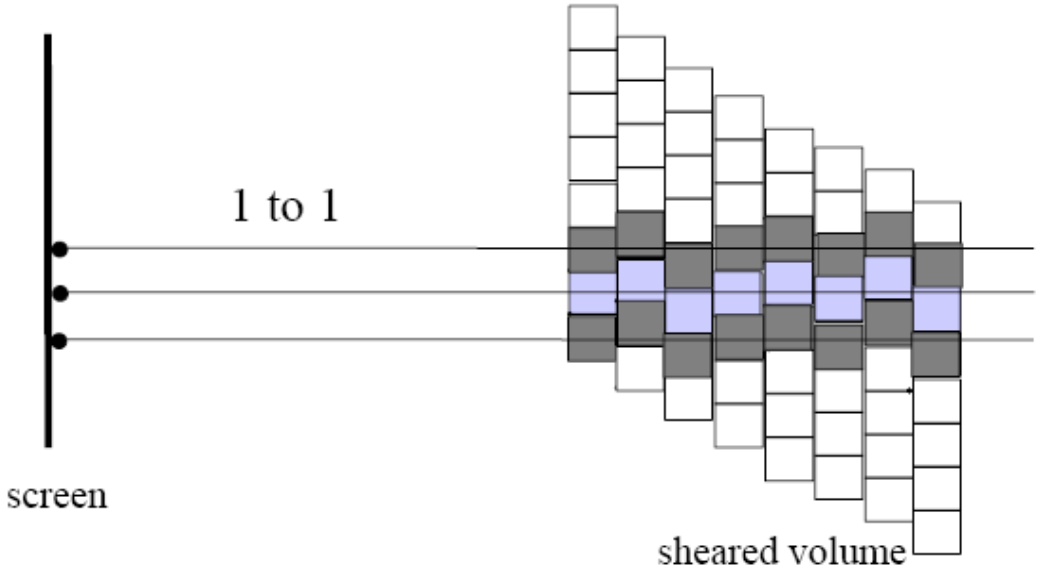
- Front-to-back ray casting

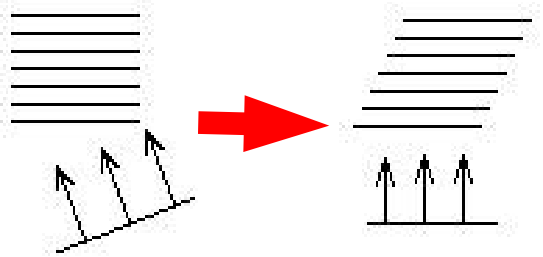


New alpha = Current Alpha + (1-Current Alpha) * Accumulated Alpha

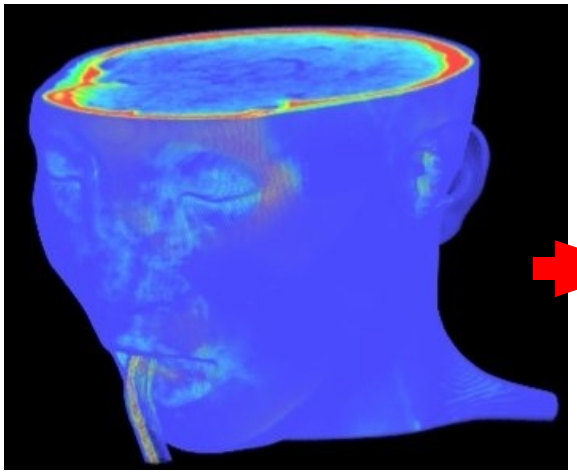
Volume Rendering

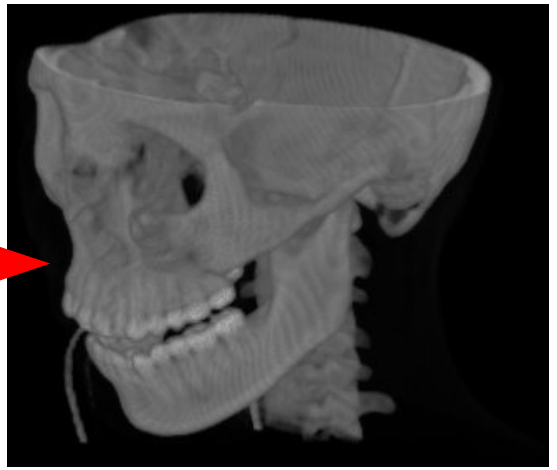
- **Advanced** Volume Rendering
  - **shear-warp algorithm**
    - **shear volume** so rays remain perpendicular
    - **ray casting** in sheared space

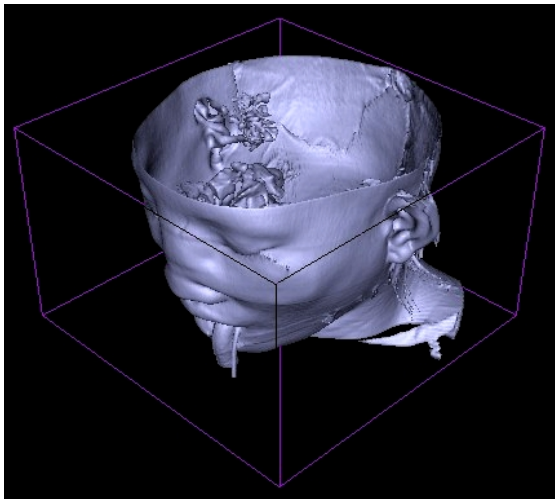


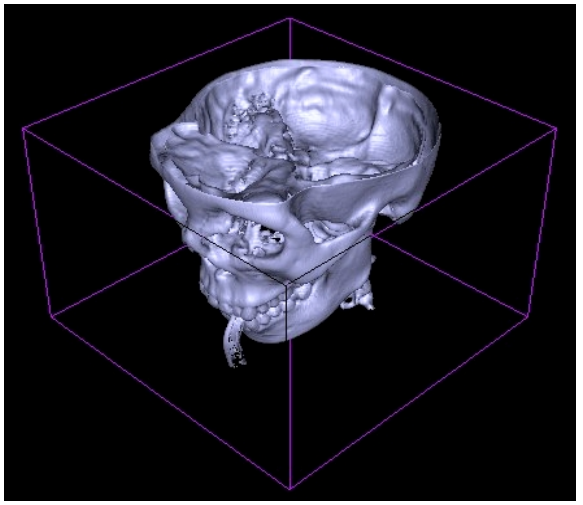


Volume colour / opacity & illumination





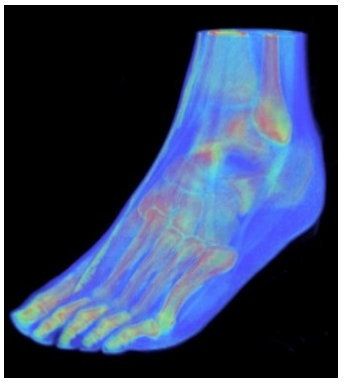


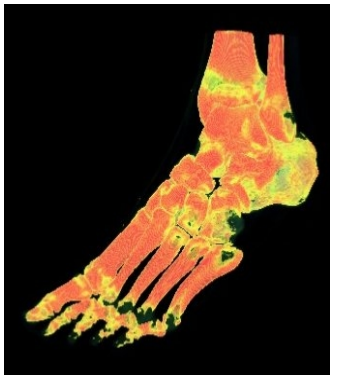


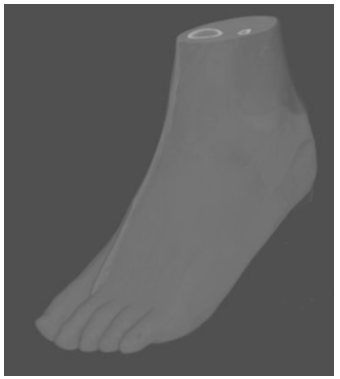
280 CT units

1200 CT units

volume illumination

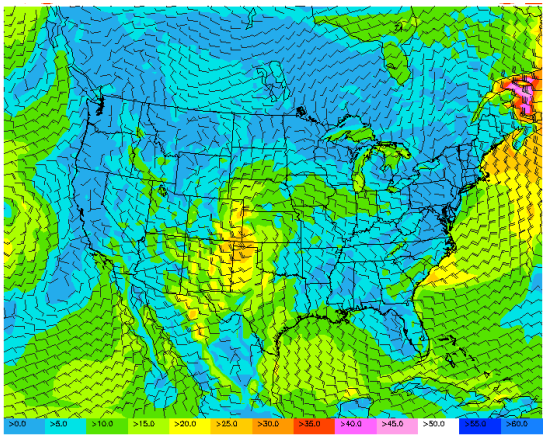


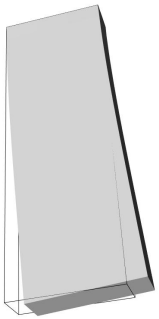


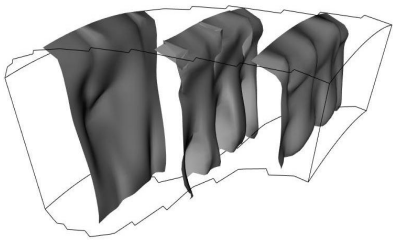


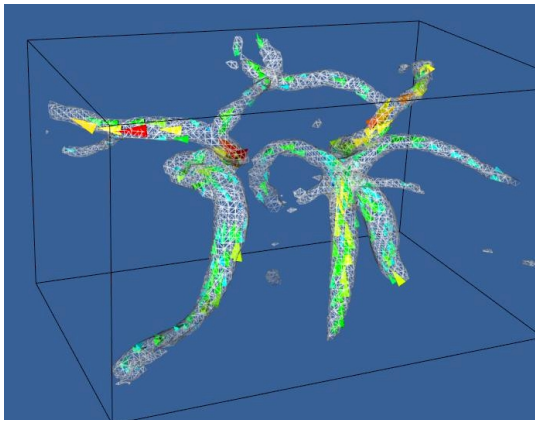
Vector Visualisation

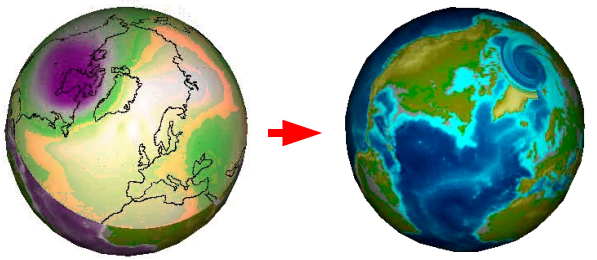
- **Local View** : visualise flow **wrt fixed point**
  - oriented **lines**, **hedgehogs** & **glyphs**
  - **colour mapping** vector components
  - **warping**
  - **displacement** plots
  - **animation**



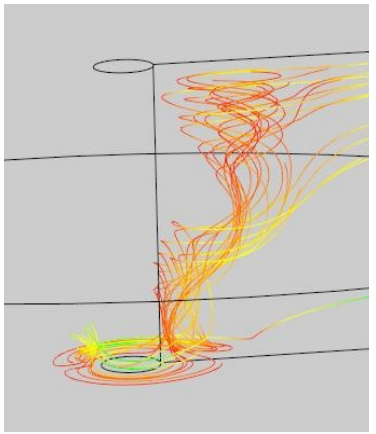


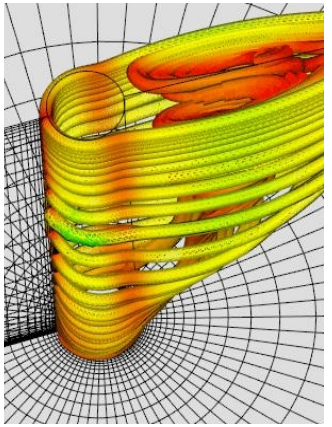




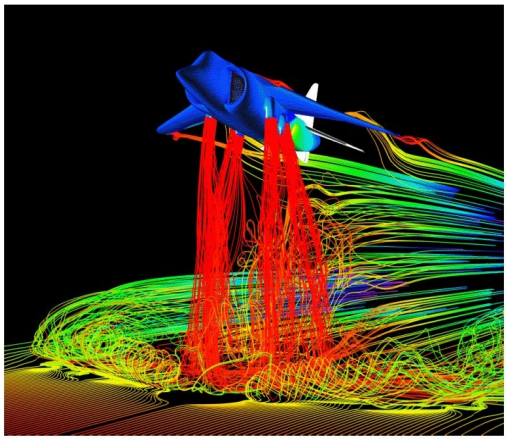


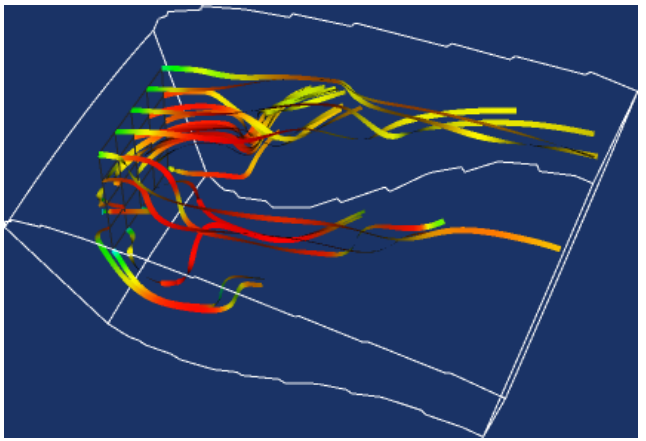
Vector Field & Flow Visualisation

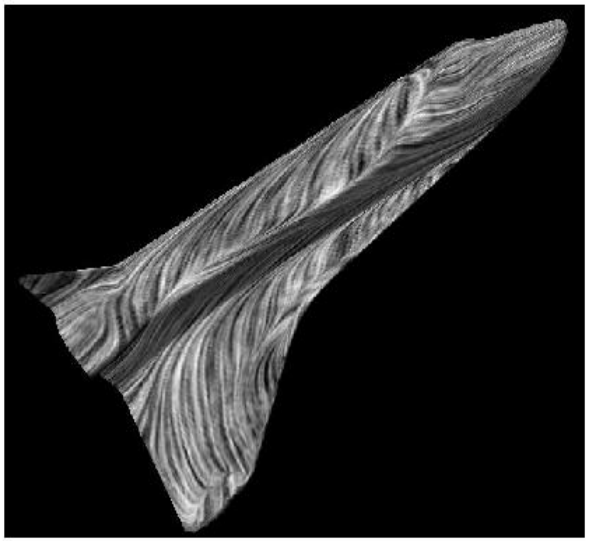




- **Streaklines** : unsteady flow
- **Streamlines** : steady flow
  - visualising transport
- Extension : stream **ribbons & surfaces**
- Image based methods : **LIC**

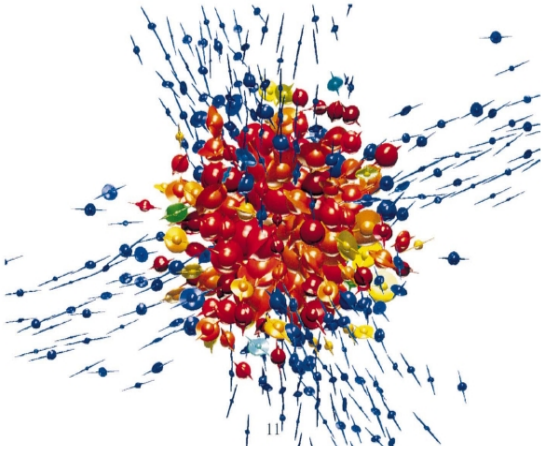


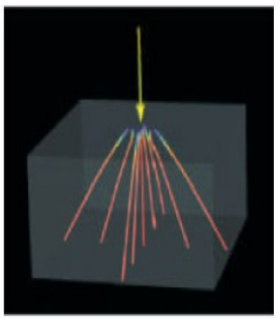


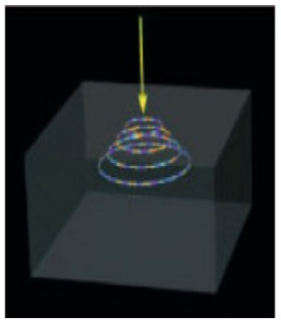


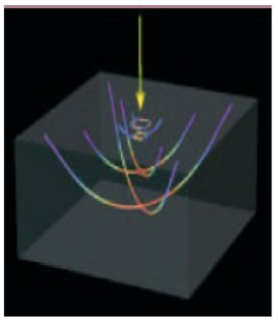
Tensor Visualisation

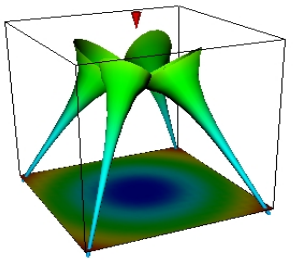
- **Tensor** : table of rank *k* in $\mathbb{R}^n$
  - *source :* ***stress, strain and MRI***
- Limited to **rank 2 tensors in** $\mathbb{R}^3$
  - obtain eigen vectors and values from **eigenanalysis**
    - **result** : 3 orthogonal vector fields
  - 3D glyphs (ellipsoids)
  - vector methods
  - **Stream lines, Hyper-streamlines**

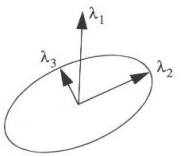






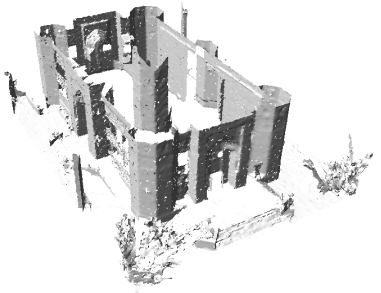


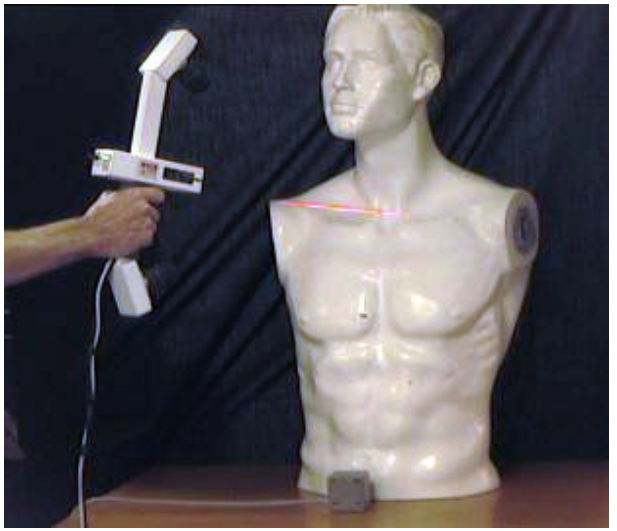


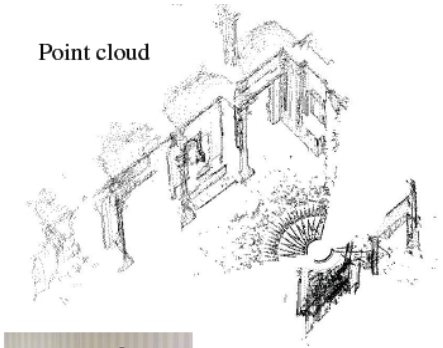


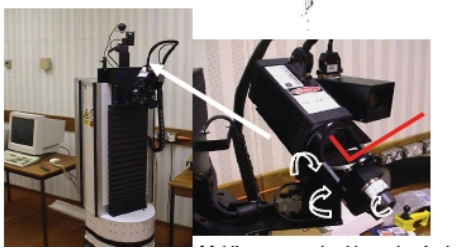
Seeing the real world .....

- Environment & Object Capture
  - **stereo vision** & **laser scanning** techniques



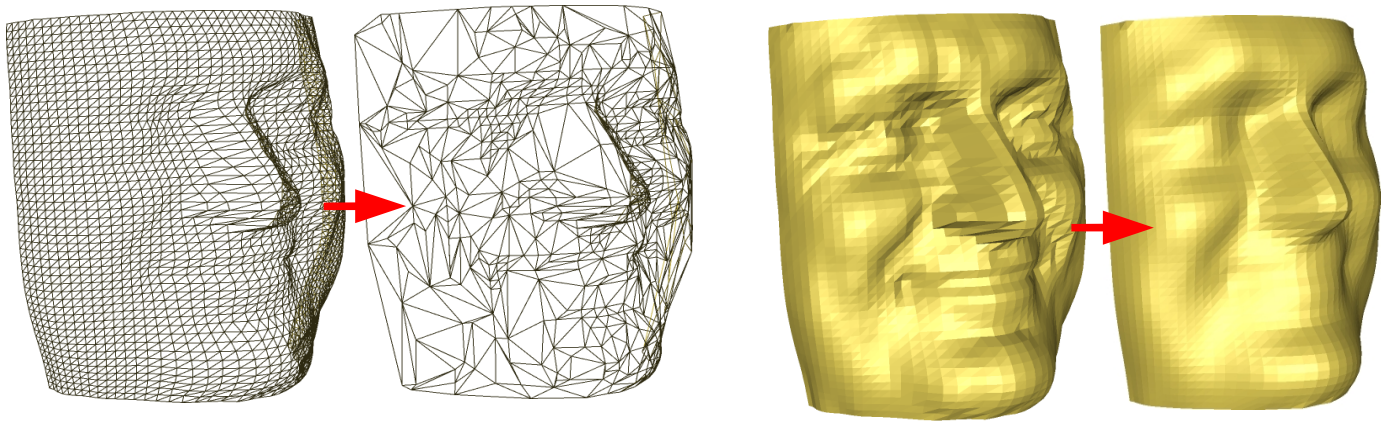






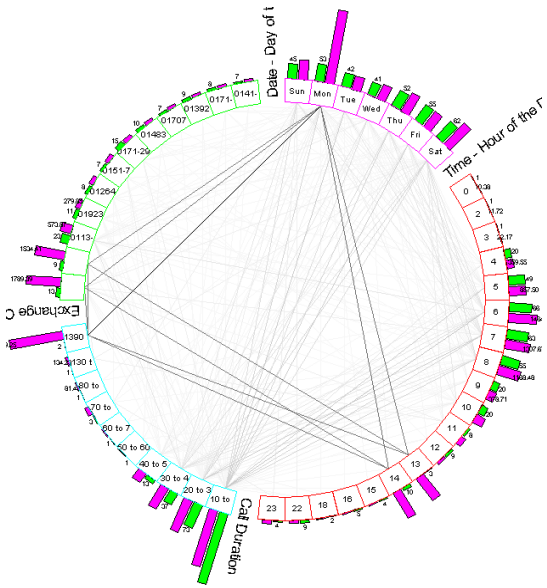
Processing the data

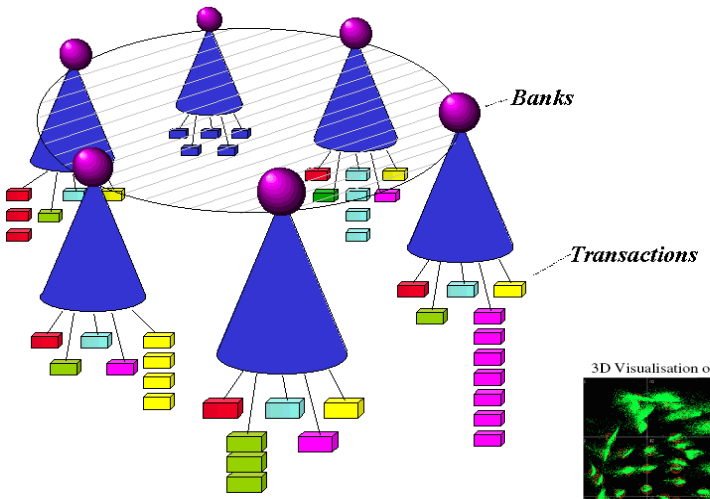
- After capturing the data we need to process the data
  - **Registration**
  - **Conversion of point clouds to surface meshes**
  - **decimation**
  - **smoothing**

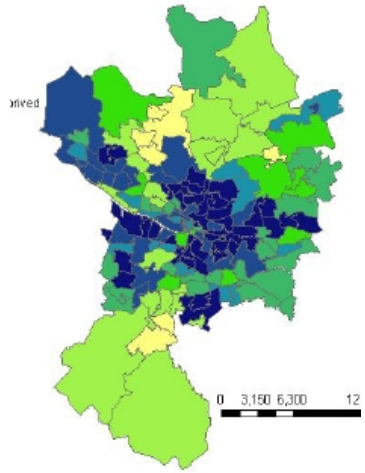


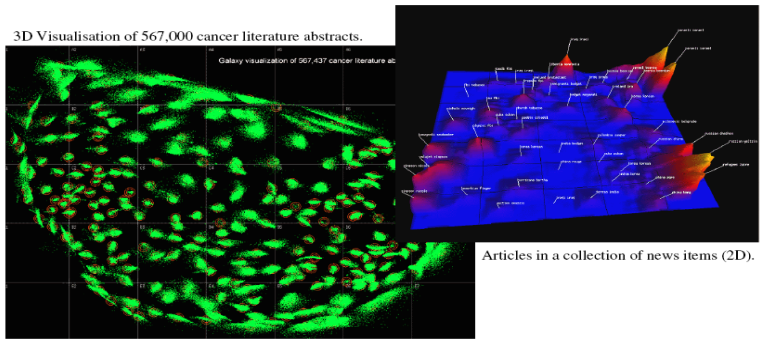
Visualising Abstract Information

- constructing topology in otherwise disjoint data measurements for visualisation : **information visualisation**
- Visualisation of **Connectivity**
  - identify complex relationships – **"visual data mining"**
- Also **: geo-spatial, documents**







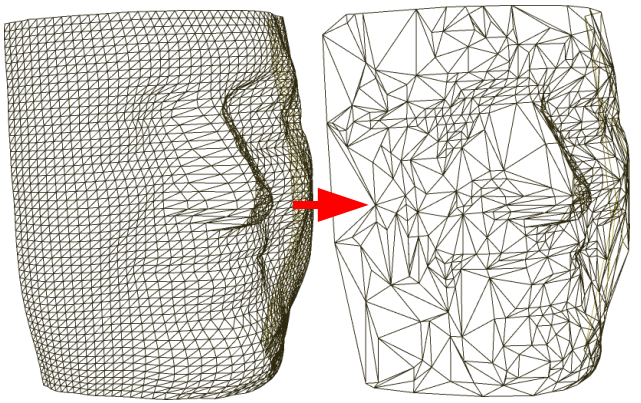


Theme : data representation & transformation

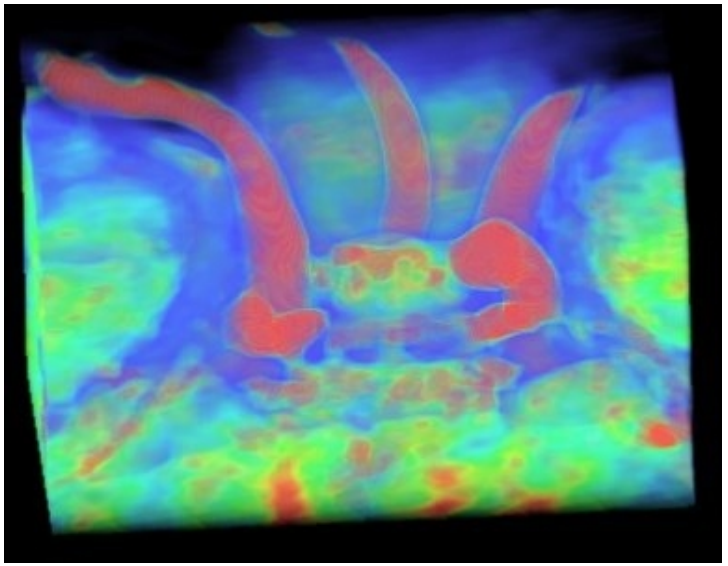
- What is our **data representation** ?
  - **topology** / **geometry** / **attribute** type
  - *topology determines interpolation*
- How can we **transform that representation in order to visualise** the information it contains ?
  - scalars to {colour | opacity | iso-surface .... }
  - vectors to {lines | glyphs | displacement .... }
  - tensors to {vectors (!) | glyphs | .... }
  - .....

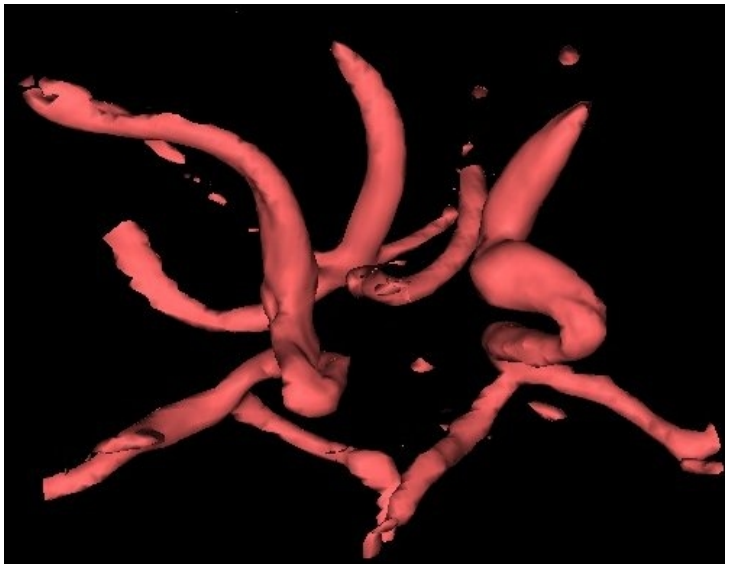
Theme : *doing it efficiently*

- Typical visualisation problem:
  - "I have a **HUGE DATASET** and I want it **NOW, RIGHT NOW in REAL-TIME"**
  - *why ?* - **interaction is real-time**
- We have to **think about efficiency**
  - of **representation**
    - *data reduction strategies*
  - of **transformation**
    - *efficient interpolation, rendering .....*

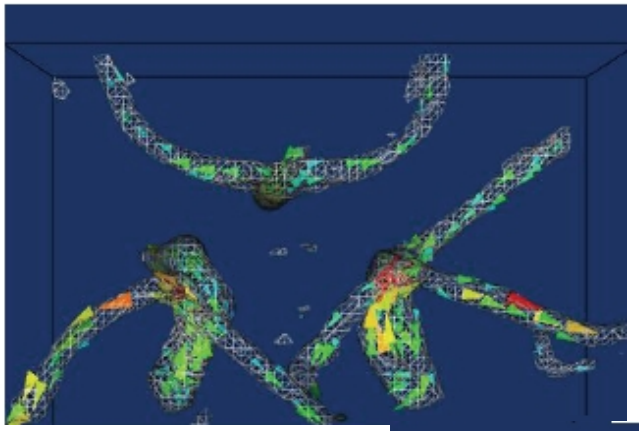


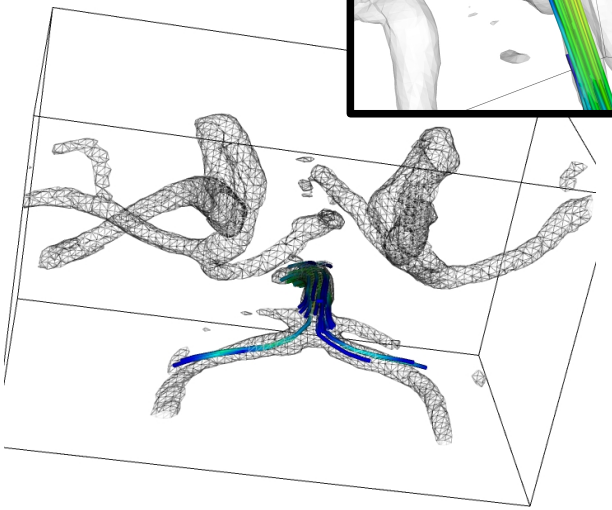
Putting it all together .... e.g. arteries

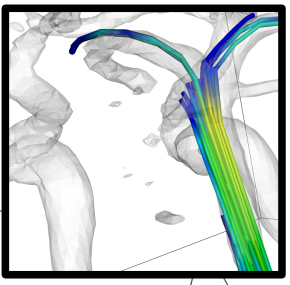


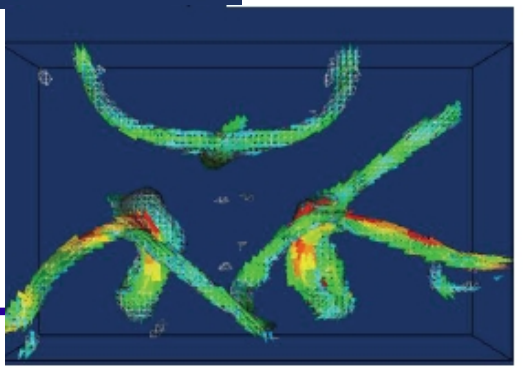


- Same data visualised using multiple different methods
  - which is best?









VIS exam

- Examinable course content:
  - **all material** presented in lectures is examinable
    - **if it appears in a lecture note, it is examinable**
  - **you will not** have to write VTK code in the exam

- What to revise ? : **everything**
- *Reading* : textbook reading and web links are provided **to aid your understanding of the examinable lecture content**

What you *should* have learned ?

- How do we **design effective visualisation systems** ?
  - ***Think*** : data representation / transformation / architecture
- What is the **best visualisation technique for a particular problem**?
  - ***Think*** *: What are we trying to see in the data?*
- What are the **limitations of a particular visualisation technique**?
- What **aspects of a problem influence visualisation** ?
  - ***Think*** : data size / dimensionality / structure / attributes

Final Course Notices

- **Lecture Notes** (& background reading / VTK examples)
  - http://www.inf.ed.ac.uk/teaching/courses/vis/#notes
- **Current Assignment**
  - http://www.inf.ed.ac.uk/teaching/courses/vis/#assignments
  - **Due** 9nd **April @ 5pm**
  - *N.B. different UG4 / MSc versions*

Thanks a lot!!!