Visualisation

UG4 / M.Sc. Course – 2008

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Overview

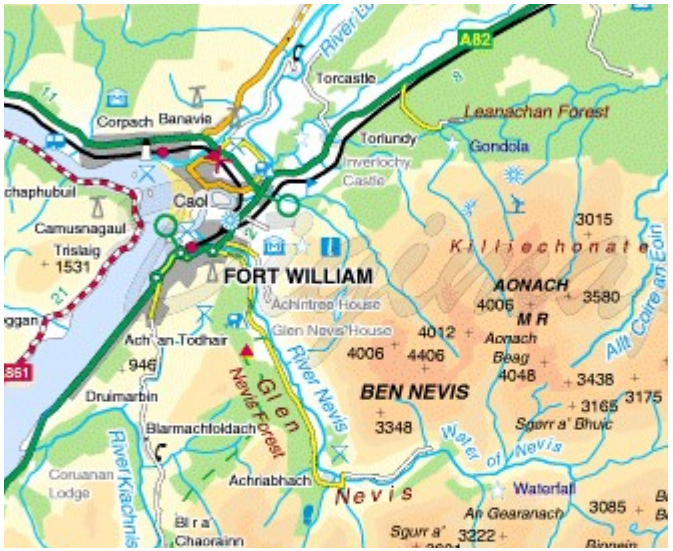
- What is visualsation
- Visual Data Analysis
- Features of the visualisation problem
- Visualisation
  - Multi-dimensional
  - Interactive
  - Data transformation
  - Flow of data
- What we do in the course
  - Data representation,
  - Data conversion
  - Techniques to handle 3D data
- Relationship of Visualisation and computer graphics, computer vision
- Data source of visualisation

So what is visualisation?

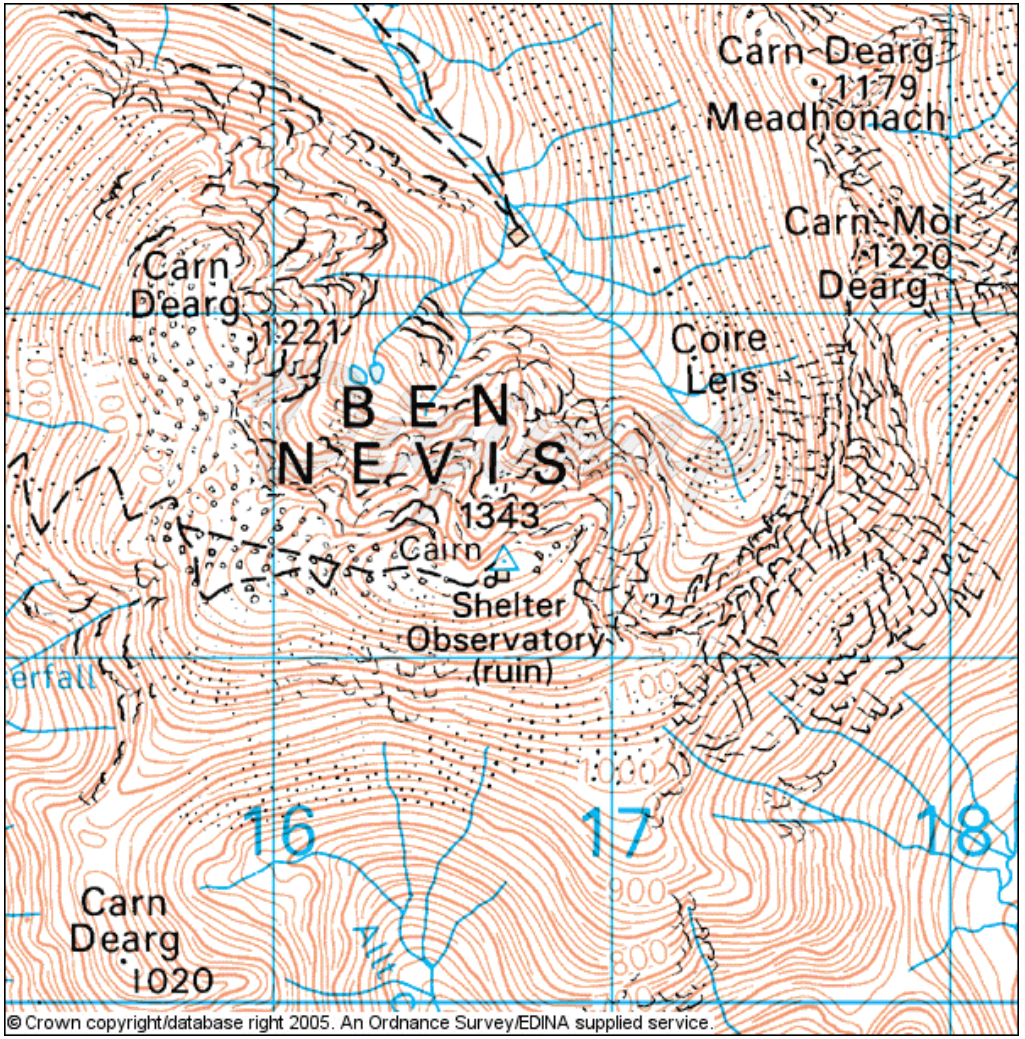
- Application of interactive 3D computer graphics to the understanding data.
  - **“visual data analysis”**
  - interactive viewing, understanding and reasoning process
- **Conversion of numbers → images**
  - humans are generally poor at raw numerical data analysis
  - human visual reasoning allows robust analysis of visual stimuli

    → *convert numerical analysis into visual analysis*

Simple Example : Maps



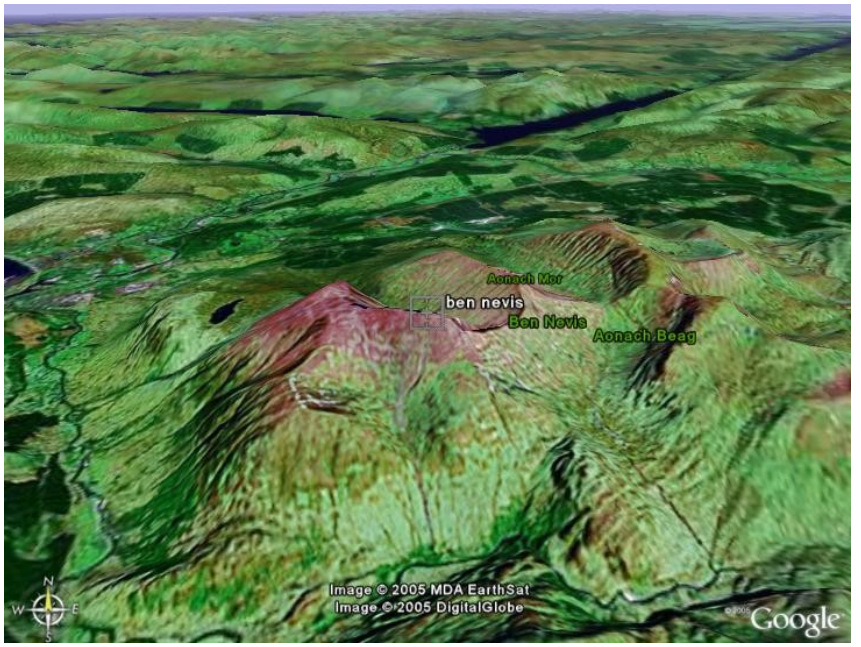
Ben Nevis – Scotland's Highest Mountain (1343m / 4409ft)
Maps: © Crown copyright



Contours represent changes in height on a 2D map
– *so what is the shape of this famous mountain?*

Simple Example : Maps

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



Ben Nevis – visualisation of 3D satellite data
http://earth.google.com

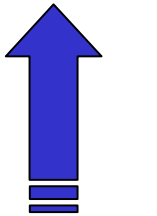
.... but with 3D graphics we can represent the shape of the mountain directly
- we can improve the visualisation of this height data by viewing it in 3D

The traditional 'scientific' process

- the *creation* of knowledge

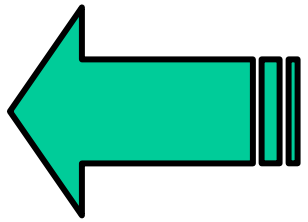
Knowledge
(Scientific papers, business strategy, a medical diagnosis etc).

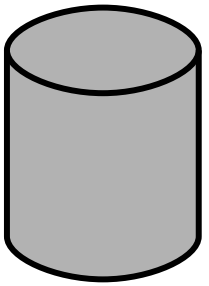
Observations
(could be scientific, medical or business sales figures etc).



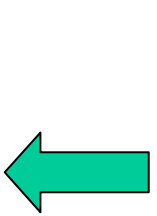
Some analysis?

Human 'expert'





Numbers



The visualisation process

- the effective creation of knowledge

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

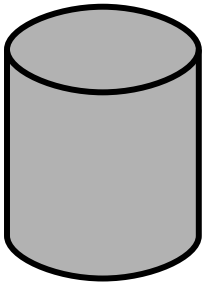
Observations
(could be scientific, medical or business sales figures etc).

Visualisation algorithms

Human 'expert'

Interaction

3D Computer Graphics



Numbers

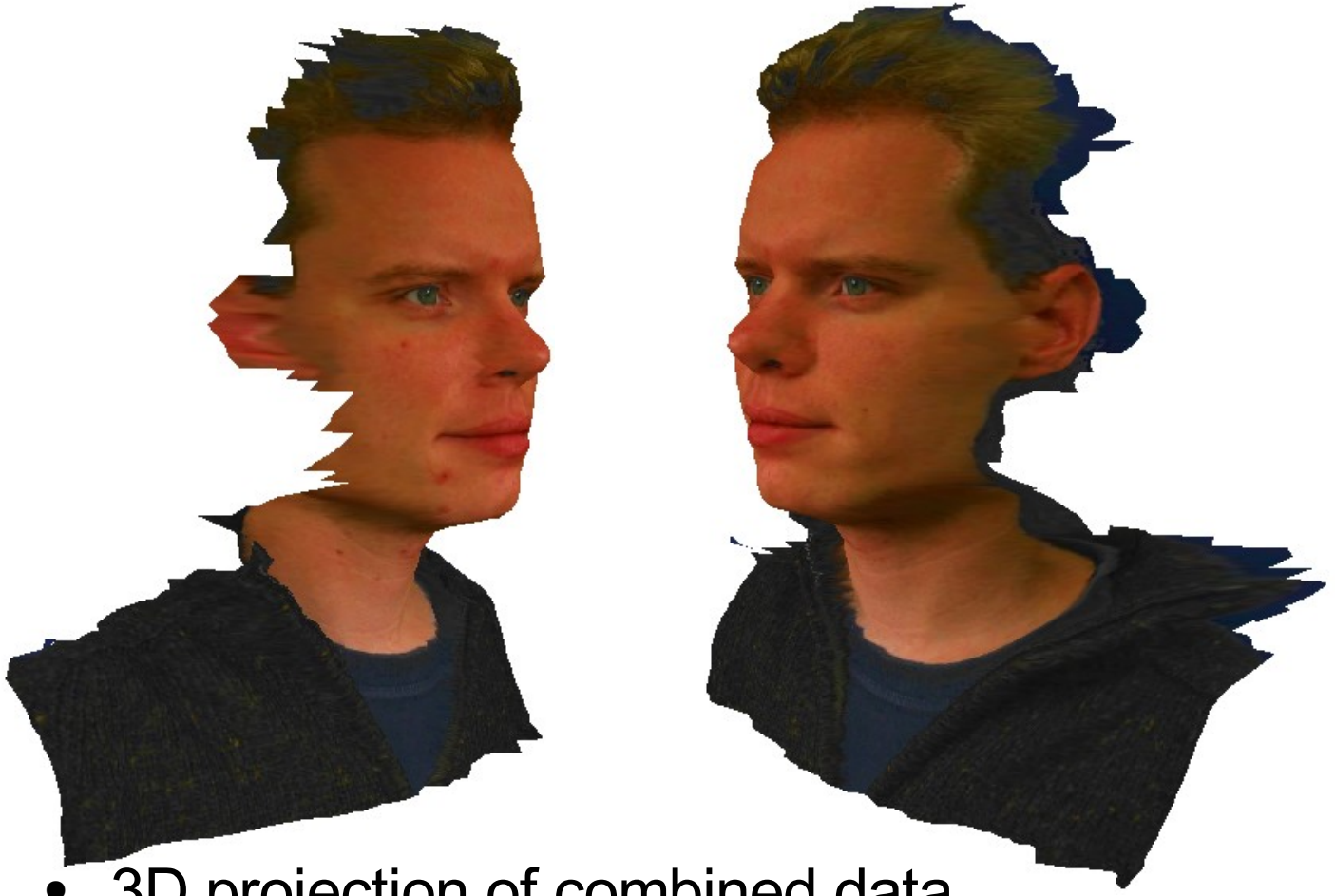
Visual Data Analysis

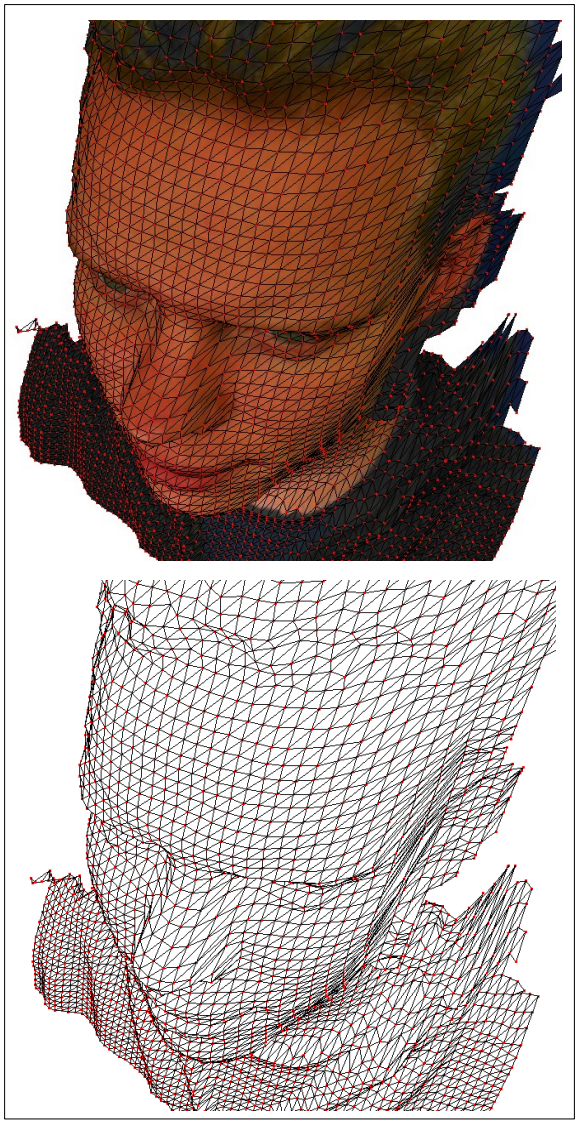
- "presenting data in a convenient and efficient visual form for *human visual analysis*"
  - Combining multi-dimensional data into a single image so that it is easy to understand
  - Extracting important features and emphasising that
    - Extracting important surface data from volume data
    - Coloring it in various ways so that it is easy to understand

Example: Basic Presentation

- 2D Colour Photograph and corresponding depth information
  - human viewer left to correlate the data

Example : Visualisation

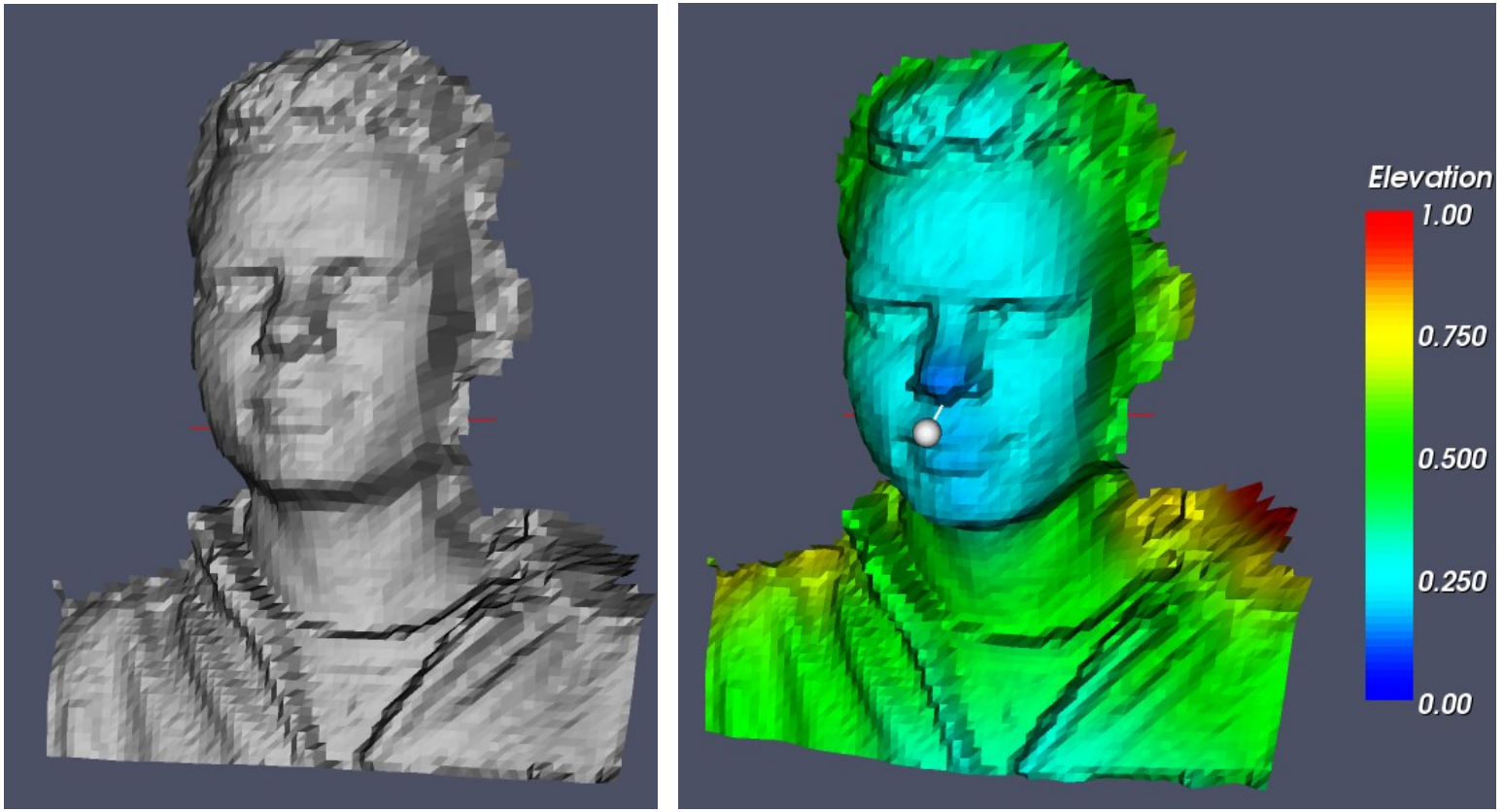




- 3D projection of combined data
  - data relationship = pixel location in 2D images
  - transformation = 3D projection

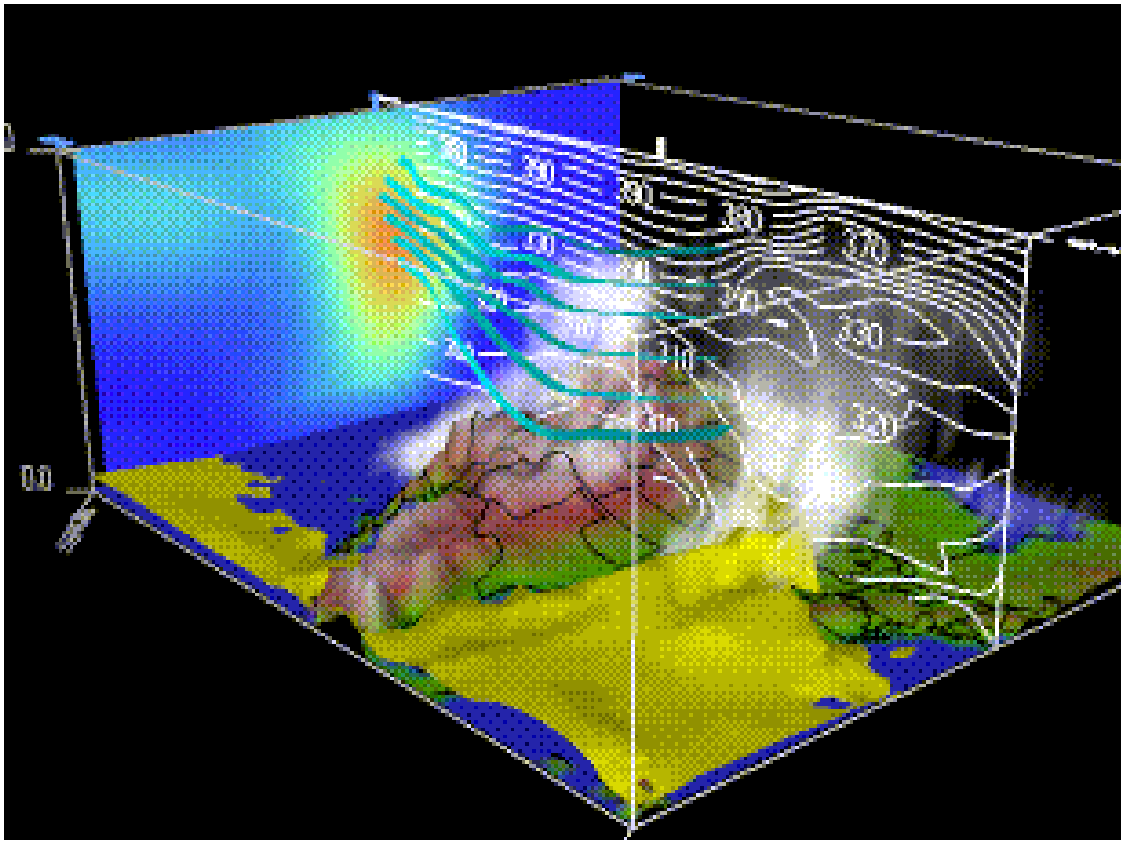
Representation = 3D mesh

Example : Visualisation



- 3D projection of combined data
  - colour removed, 3D shape only
  - use of colour to show relative elevation of features

Example : this all comes from a volume data

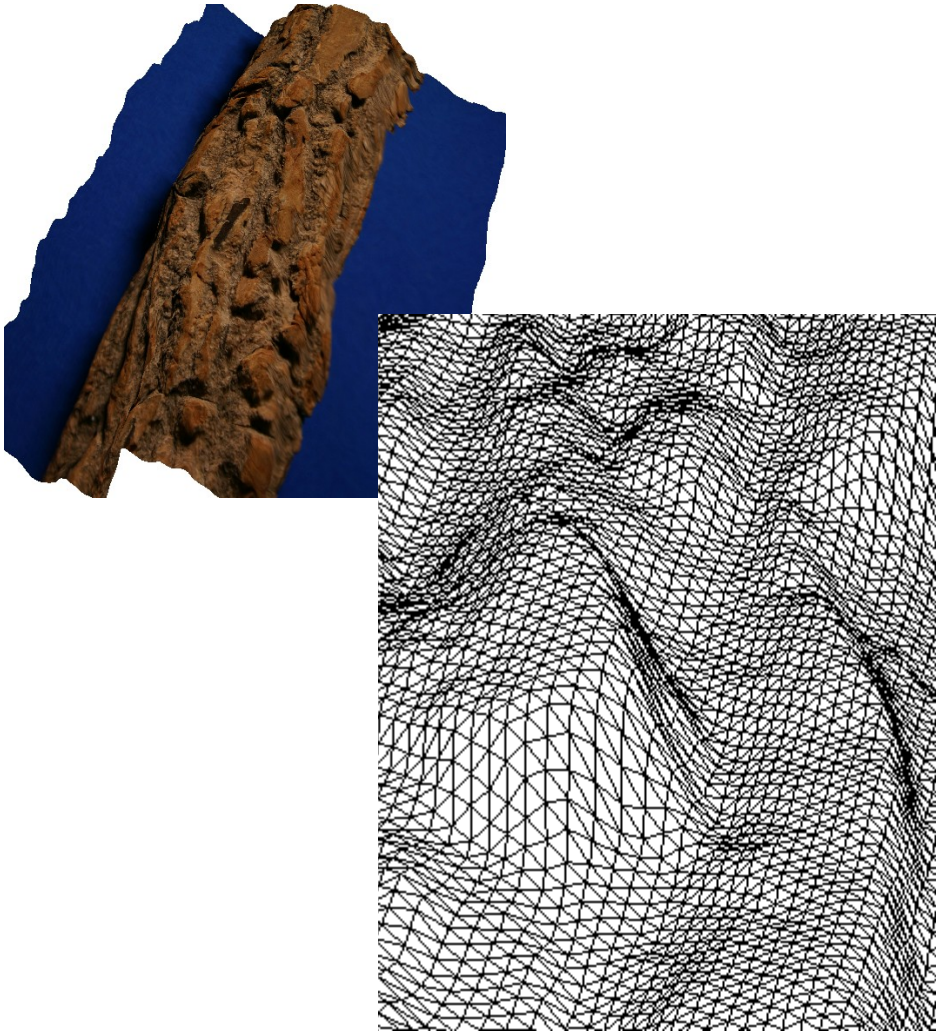


Source:
http://www.ssec.wisc.edu/~billh/vis5d.html

- 3D visualisation of:
  - terrain (position x,y,z, type = colour)
  - temperature, wind speed (rear and orthogonal display)

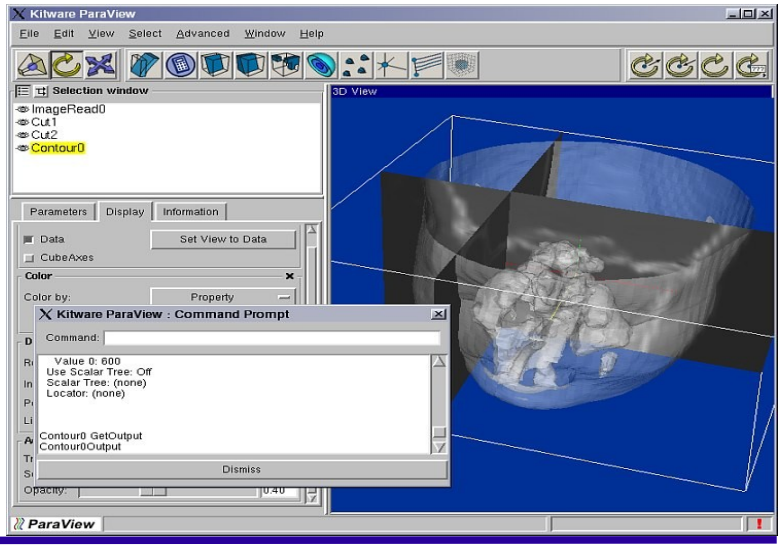
Features of Visualisation : 1

- **Multi-dimensional Data**
  - data with 3 or more dimensions ($\mathcal{R}^N$, N >= 3)
  - Convert the data into low dimensions so that people can acknowledge features



Features of Visualisation : 2

- **Interaction**
  - user driven process
  - user does analysis
    - computer does visualisation
  - Unlike numerical analysis of statistics the user does the analysis

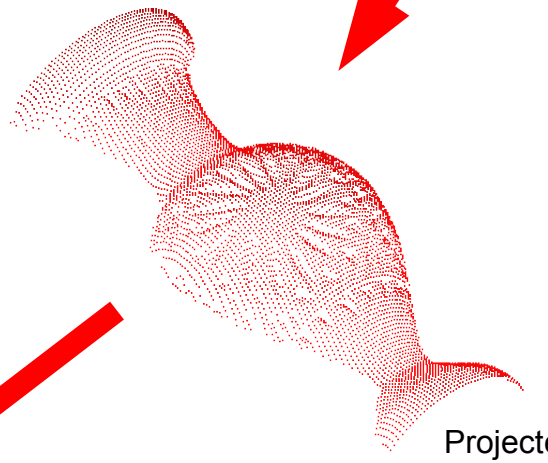


Features of Visualisation : 3

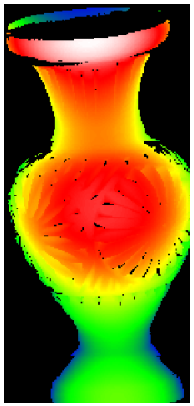
- **Data transformation**
  - data is repeatedly created and modified to enhance meaning to the user

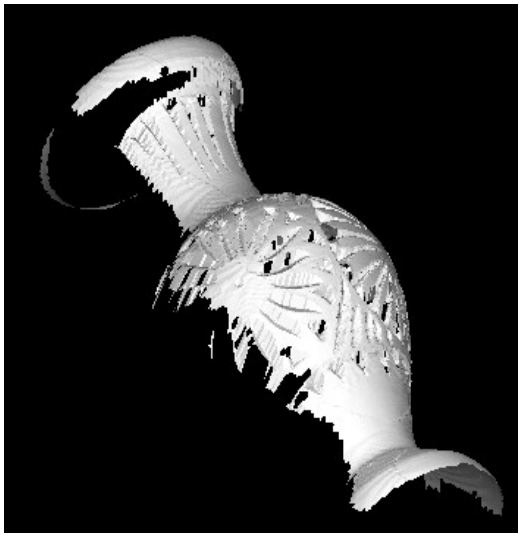
```
202.0000000000 -221.0050048828 -170.1450042725
202.5000000000 -220.5050048828 -169.8619995117
202.5000000000 -221.0050048828 -169.7920074463
209.0000000000 -296.5029907227 -165.5749969482
.....
```

Raw 3D points from a range scanner



Projected 3D point cloud

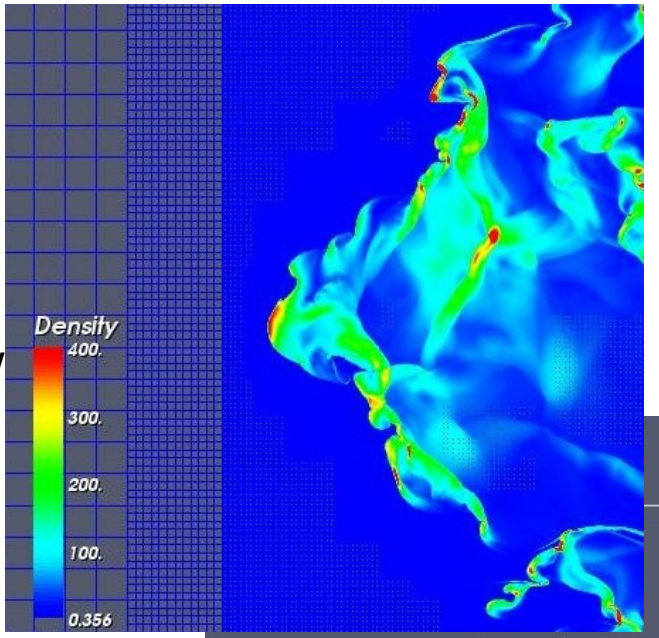


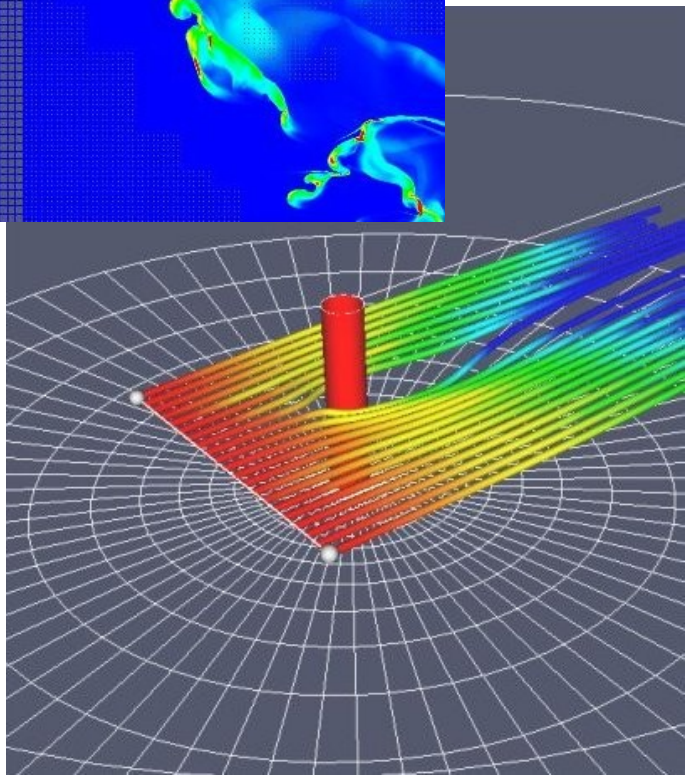


Triangulated 3D surface + associated depth colouring

Features of Visualisation : 4

- **Flow of data**
  - visualising large scale time varying (temporal) data
    - e.g. weather, financial prices, air flow
    - use of animation in visualisation
    - visualisation of flow





http://www.paraview.org/

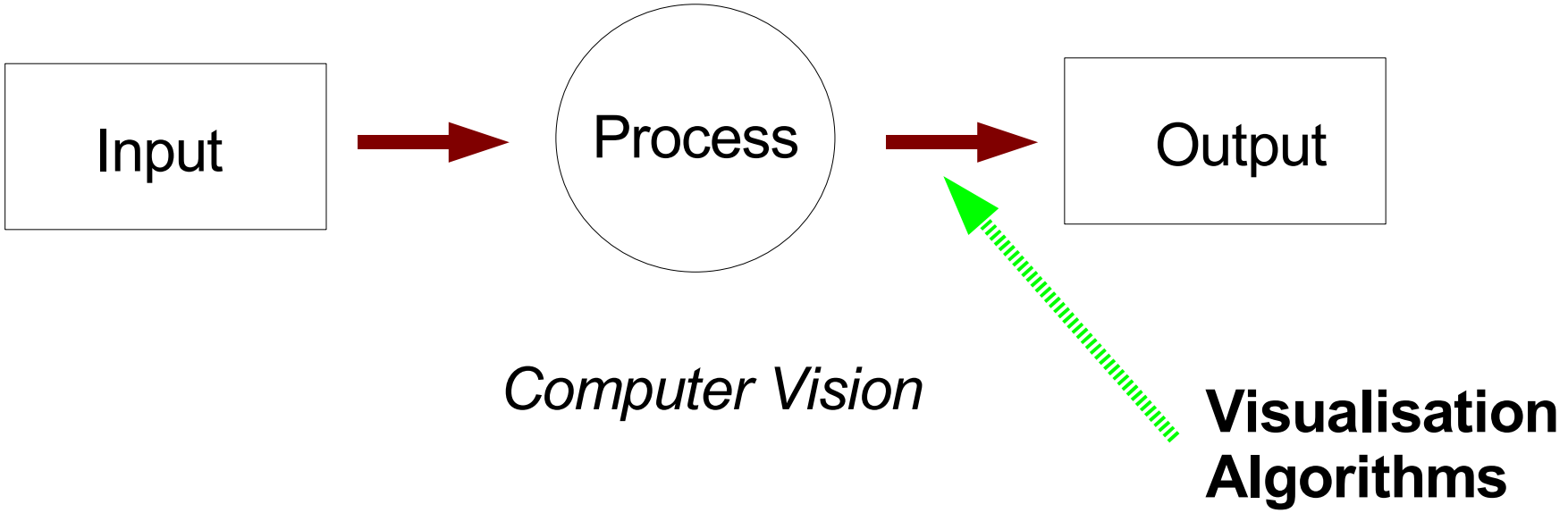
What's in this course?

- **Data representation**
  - Surface data, volume data, point clouds, flows, vector fields
- **Data conversion**
  - **Volume -> surface**
  - **Point clouds -> surface**
  - **Volume -> image**
  - **Flow data -> surface, image**
- Techniques to handle 3D data
  - Practical problems of visualising and acquiring 3D data

Focus on 3D Graphics

- 3D graphics are our tool in visualisation
- We can
  - interactively change color attributes
  - view the results from various directions

Visualisation & Computer Vision



- **Computer Vision (CV):** computer analysis of visual information
  - automated visual reasoning
- **Visualisation:** computer presentation of that visual information
  - commonly part of the output process in the CV pipeline (especially 3D capture)
  - also used for evaluation in CV (i.e. to provide insight into CV process itself)

Visualisation is data-orientated

- 3 main sources of visualisation data:
  - **Scientific / Medical Visualisation**
    - visualising results of simulations, experiments or observations
    - Frequently data is multi-dimensional
  - **Information Visualisation**
    - Visualisation of abstract, usually discrete data
    - e.g financial data, web site hits etc.
  - **Real-world Data**
    - 3D capture technologies are reaching maturity
    - Application : Virtual Reality, Games

Example : Medical Imaging

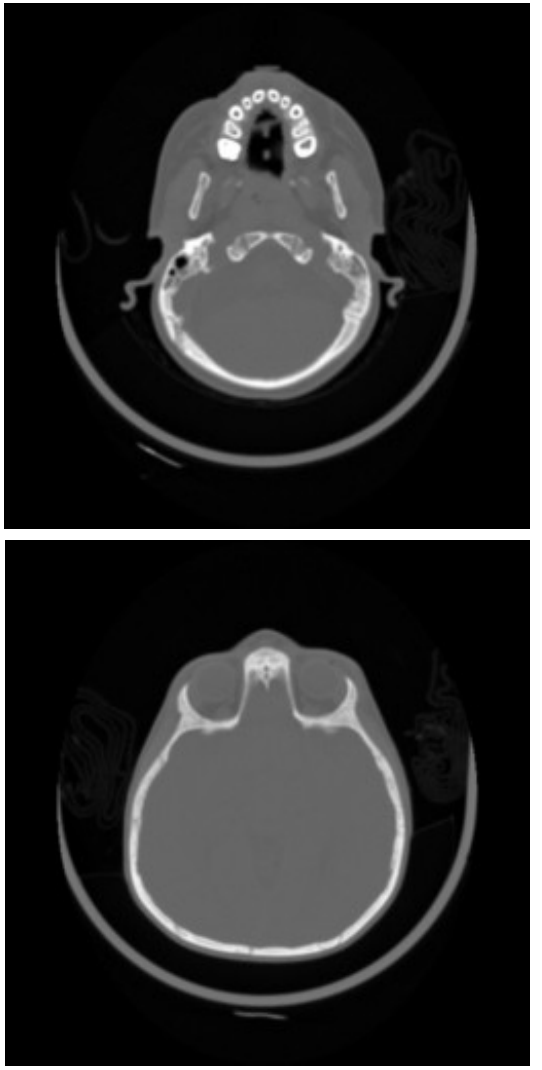
- Computer imaging in medicine:
  - *Computed Tomography* (CT) imaging uses pencil thin X-ray beams
  - *Magnetic Resonance Imaging* (MRI) uses large magnetic fields

Chest CT section

Magnetic Resonance Image showing a vertical cross section through a human head.

Example : Medical Imaging

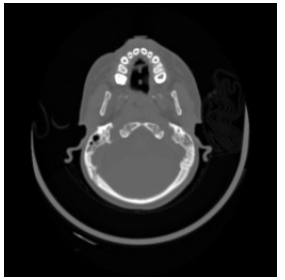
- Collect data as *slice planes* from patient
- Numbers from scanners
  - X-ray attenuation (CT)
  - Nuclear spin magnetization (MRI)
  - Large amounts of data
  - Difficult to interpret
    - fairly abstract physics based concepts (for a computer scientist or medical practitioner!)

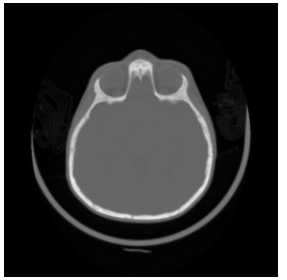


2D images from CT data slices

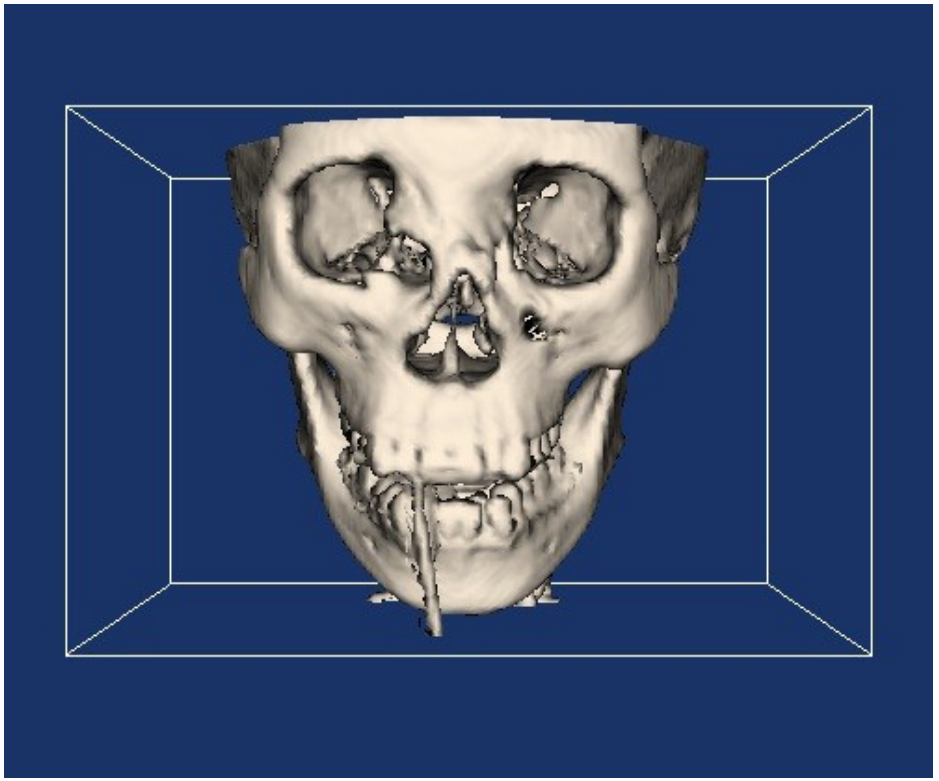
3D surfaces from CT slices

- Many planar slices (2D) can be combined (in topological order) to form a 3D volume of data
  - i.e. stack of 2D images





- Volume can be processed and rendered to reveal complete anatomical structures



Course Syllabus

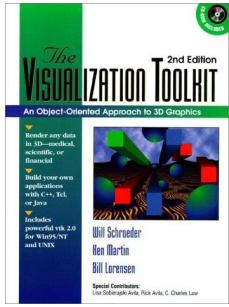
- **Data Representation**
  - Data geometry and topology
  - Surface and volume representations
- **Systems architecture for Visualisation**
  - The Visualisation Pipeline
- **Fundamental algorithms**
  - 2 & 3D Contouring, Colour-mapping
  - Volume rendering
- **Advanced algorithms**
  - Flow visualisation
  - Vector visualisation
  - Tensor visualisation
- **Information visualisation**
  - Networks and trees, documents
- **Real world objects**
  - Visualisation of real objects & environments
  - Acquisition of 3D data

Course Outline

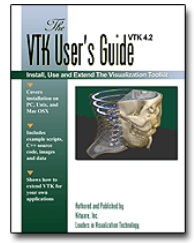
- **18 Lectures**
  - lecture notes on-line (http://www.inf.ed.ac.uk/teaching/courses/vis/)
  - background reading (mainly on-line, also textbook)
- **2 Assessed Practicals**
  - 2 programming tasks
  - Visualisation Toolkit – VTK
  - prior weekly practicals introducing VTK
- **Assessment**
  - 1.75 hour examination (70%)
  - 2 practical assignments (15% each)
    - (variation between UG4 and M.Sc. requirements)

Textbooks

- **Non-essential**
  - majority of VTK information on-line (although in terse form)
  - *No single book covers all of the course*
- ***Maybe of use:***
  - *Schroeder/Martin/Lorensen – The Visualization Toolkit : An Object-Orientated Approach to 3D Graphics*
    - *2nd or 3rd Edition. 3rd Edition ISBN 1-930934-12-2*
    - *Available in Library (JCMB). Limited availability in UK. Amazon marketplace £~20+*



  - *Schroeder/Martin/Lorensen - The Visualization Toolkit User's Guide*
    - *Most recent edition ISBN 1-930934-13-0*
    - *Available in Library (JCMB). Limited availability in UK.*
  - *http://public.kitware.com/VTK/buy-books.php / http://www.amazon.com (expensive shipping)*



Summary

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  - Visualisation
    - Multi-dimensional
    - Interactive
    - Data transformation
    - Flow of data
  - What we do in the course
    - Data representation,
    - Data conversion
    - Techniques to handle 3D data
  - Relationship of Visualisation and computer graphics, computer vision
  - Data source of visualisation
- ***Next lecture*:** computer graphics as our visualisation tool