COMPSCI 716 S2 T Visualization

Part 2 – Scientific and Biomedical Visualization

Burkhard Wünsche
Division for Biomedical Imaging & Visualization
Graphics Group

Who is Burkhard?

- Born in München (Germany)

- Studied in Kaiserslautern (Germany)

- PhD in Biomedical Visualization
- Research Interests:
  - Computer Graphics, Biomedical Imaging, Scientific Visualization, Geometric Modelling, Computer-Aided Geometric Design, Game Technology, Simulation Algorithms, Information Visualization.

COMPSCI 716 S2 T – Visualization

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  Office hours: Friday 9-11am

COMPSCI 716 S2 T Visualization – Lectures

Week 6 (21st - 25th August):

Monday 1.30-2.30pm & Wednesday 1.30-3.30pm
Room 721-201 (Tamaki Campus)

Week 7-12 (11th September - 20th October):

Monday 1-2pm & Wednesday 3-4pm
Rm 279, CompSci Seminar room, City campus

COMPSCI 716 S2 T Visualization – Assignments

Part 2 has two individual assignments:

Burkhard's Assignment 1
Published: probably Wednesday, 23rd August
Due date: probably Monday 25th September (see assignment handout)

Burkhard's Assignment 2
Published: probably Wednesday, 27th September
Due date: probably Friday 20th October (see assignment handout)

NOTE: No assignments will be accepted after the due day.

PART 2 - Scientific and Biomedical Visualization

Content (subject to change)

1. Introduction
2. VTK – The Visualization Toolkit
3. Visual Perception and Cognition
4. Data Transformation and Reconstruction
5. Visualization Techniques for Scalar Fields
6. Visualization Techniques for Vector Fields
7. Visualization Techniques for Tensor Fields
8. Case Study – The Visualization of Neuroanatomy from DTI Data

Chapter 1 - Introduction

1.1 Reference Material
1.2 What is "Visualization"?
1.3 The Visualization Pipeline
1.4 Types of Visualization
1.5 Top Scientific Visualization Research Problems
1.6 Visualization at the University of Auckland

1.1 Reference Material

The recommended text book is:

- *The Visualization Toolkit – An Object-Oriented Approach to 3D Graphics*, Will Schroeder, Ken Martin and Bill Lorensen, 3rd edition, Kitware Inc, http://www.kitware.com .

The following text is recommended reading:

- "OpenGL Programming Guide: The Official Guide to Learning OpenGL", Woo, Neider, and Davis (2nd or 3rd edition). Addison-Wesley (aka "The Red Book").
  - Available on web (with dubious legitimacy) e.g. http://fly.cc.fer.hr/~unreal/theredbook/

Reference Material (cont'd)

VTK References:

- VTK 5.0 Documentation
  - Available from the *716 Resources* page.
- VTK Homepage
  - http://www.vtk.org

OpenGL/GLU/GLUT References:

- OpenGL/GLU/GLUT man pages (see *716 Resources* page)
- OpenGL homepage: http://www.opengl.org/
  - Examples, Discussion forums, etc.
- OpenGL Examples (see *716 Resources* page)

Reference Material (cont'd)

C References:

- C Language Reference
  - "C-Reference manual" (a PostScript version of the 6th edition is available at http://www.cs.bell-labs.com/who/dmr/cman.ps)
  - DEC C Language Reference Manual - see 716 *Resources* page
- ANSI-C Standard Library
  - 716 *Resources* page or "http://www.hh.se/stud/d98rolb/ansi/main.html"
- man-pages of any UNIX implementation (eg. type 'man printf')

C++ References:

- Microsoft Visual C++ Help
- Bruce Eckel - Thinking in C++ (free online: http://www.ibiblio.org/pub/docs/books/eckel)

1.2 What is "Visualization"?

Visualization is the process of graphically displaying real or simulated data.
(Encyclopedia Britannica)

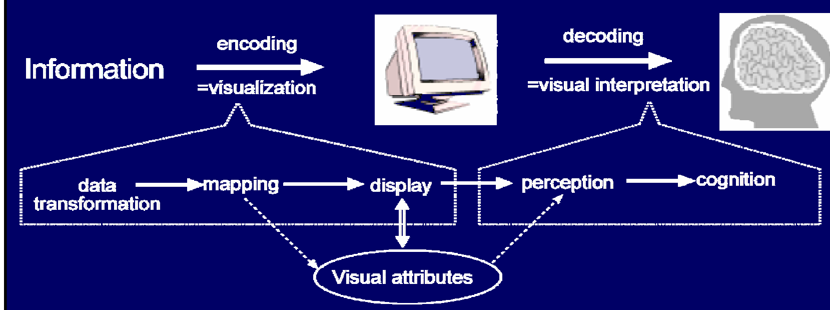
Why do we need Visualizations?

- Technology and increasing human knowledge has led to ever larger and more complex data sets.
  - e.g. advanced numerical simulations, satellite measurements, medical imaging data, census data, complex software systems
- New ways must be found to maximise the information acquired from data while minimising the cost of interacting with it.
- Visualization is an attempt to achieve this goal by transforming the data into images (scenes) that, when presented to the human observer, convey insight and understanding of the data.

Applications

- Improve understanding of data
- Convey insight into data
- Improve perception of features and patterns
- Facilitate navigation through data
- Improve interaction with data
- Improve communication of scientific results with peers and the wider community
- Fasten the development cycle by integrating visualization into simulation → Computational steering
- Education

1.3 The Visualization Pipeline



Visualization (data encoding)

Data transformation: converts raw data into a more suitable intermediate representation (e.g. resampling, interpolation, coordinate transformation).

Mapping: converts intermediate data into a number of graphical entities called visualization icons (e.g. isosurfaces, vector arrows, LIC textures, streamlines).

Rendering: Displays the graphical entities on screen or paper.

Visual Interpretation (decoding of visual information)

Visual perception: recognition of visual attributes such as colour, shape, length, contrast and texture.

Cognition: association of low and high level visual information with meaning (e.g. yellow means high temperature, vectors show the direction and speed of a water flow).

1.4 Types of Visualization

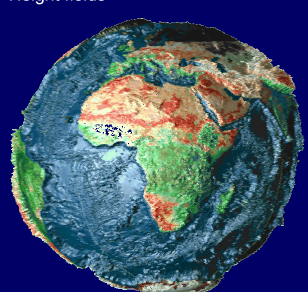
- Scientific Visualization
- Biomedical Visualization
- Information Visualization
- Software/Algorithm Visualization

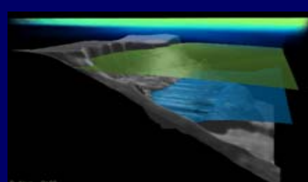
Scientific Visualization

- Used to visualize scientific data sets obtained from measurements and simulations.
  - The data sets are usually extremely large
  - Often contain multiple complex measures (scalar, vector and tensor data)
- A Scientific Data set has independent (usually space & time) and dependent variables.

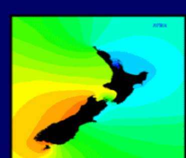
Scalar Icons

Height fields

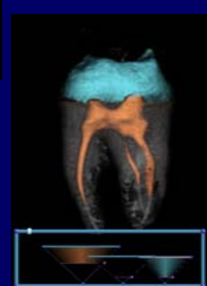




Isosurfaces

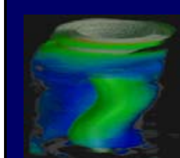


Colour mapping



Direct Volume Rendering

Vector Icons



Direct volume rendering of vector fields

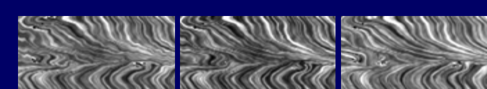
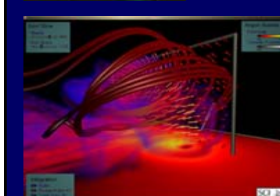
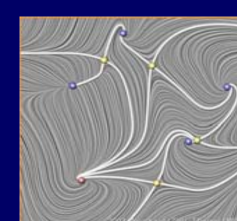


Image processing of vector fields (interpolation, smoothing, denoising …)



Streamtubes and vector errors

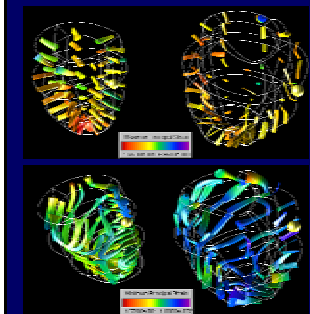
Line integral convolution



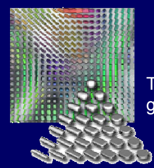
Vector field topology

Tensor Icons

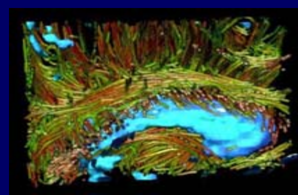
Image processing of tensor fields (interpolation, smoothing, denoising …)



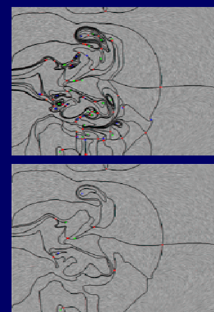
Hyperstreamlines



Tensor glyphs



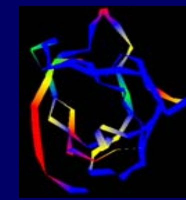
Line integral convolution

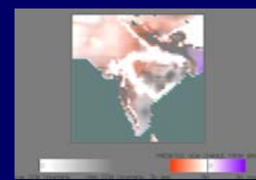


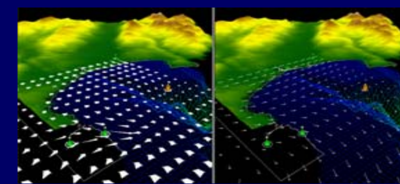
Tensor field topology

Other Visualization Techniques

- Animation
- Comparative Visualization
- Uncertainty Visualization

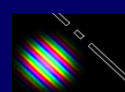


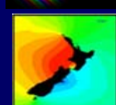


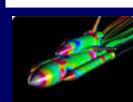


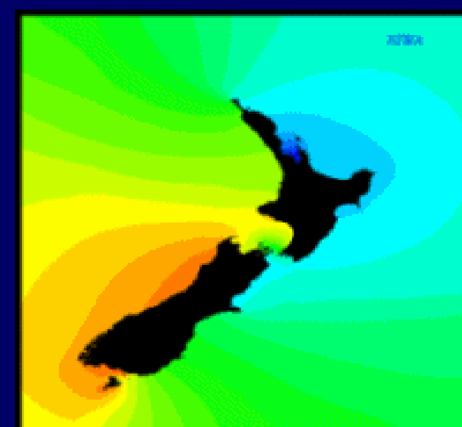
Examples

- Solution of the Schrödinger equation: Double-slit experiment with a Gaussian initial state (© Bernd Thaller)
- Primary Tide for New Zealand (© Derek Goring)
- Karman vortices (© Goddard DAAC)
- Space Shuttle Ascent Simulation (© NASA)
- Exploration of historic artefacts



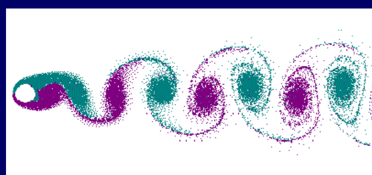






© Derek Goring, Coastal Hydrodynamics Group, Christchurch, New Zealand

Karman Vortices



© Cesareo de la Rosa Siqueira, University of Sao Paulo, Brazil © Goddard DAAC

Exploration of Historic Artifacts

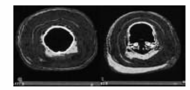
Non-destructive exploration and dissection of:

- prehistoric artifacts (dinosaur eggs, fossils in a chunk of soil)
- artifacts from ancient cultures (mummies, the 'frozen man')

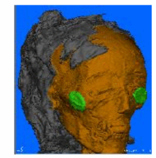
old procedure:
destructive unwrapping of the mummie

non-destructive procedure:

CT scan



CT slice reconstruction



volume rendering

artistic sketch based on volume rendering

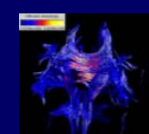
© Klaus Mueller, State University of New York at Stony Brook

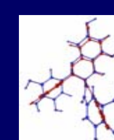
Advances in Scientific visualization

- New visualization icons
- New interaction metaphors
- Improved graphics hardware and software (programmable GPUs)
- Improved understanding of human visual perception and cognition

Biomedical Visualization

- Computer Assisted Surgery (© ZIB)
- *Nerve fibre tracts in the brain*
- Segmentation of MRI data (© Cambridge Research Systems)
- Visualization of biochemical processes (© ZIB)

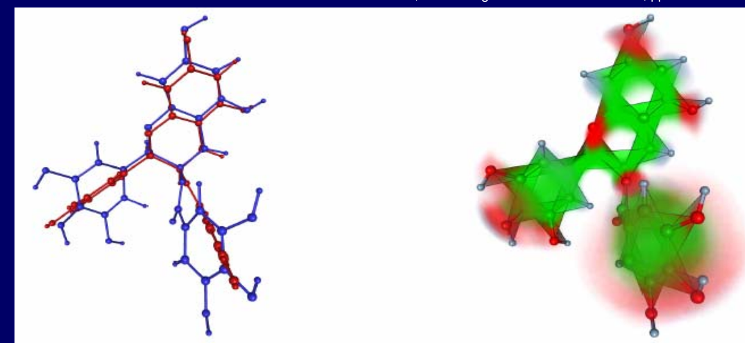




Computer Assisted Surgery

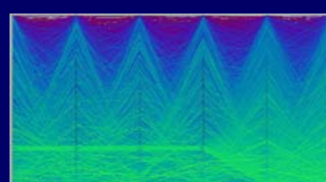
Visualization of Biochemical Processes

© 2002 Schmidt-Ehrenberg et. al., *Visualizing Dynamic Molecular Conformations*, Proceedings of IEEE Visualization '02, pp. 235-242.

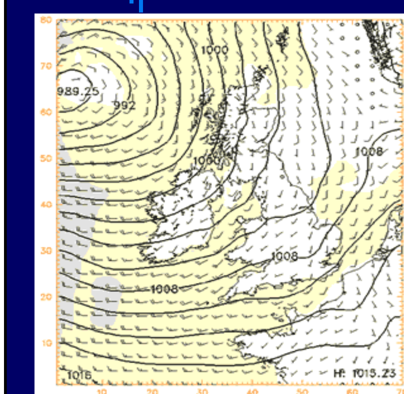


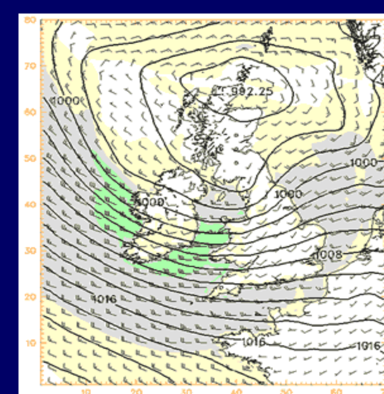
Information Visualization

- Information visualization usually deals with multi-variate data (no separation into dependent and independent variables)
- Information visualization puts more emphasis on data modelling (conceptual modelling)



Example – Weather forecast

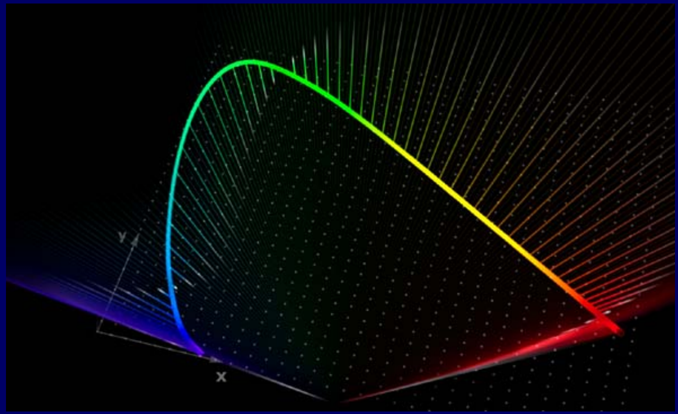




Example – London Tube Map

Example – Visualization of Colour Spaces

© 2005 Sony Picture Image Works, Visualizing the XYZ Color Space, SIGGRAPH 2005 Electronic Theatre.

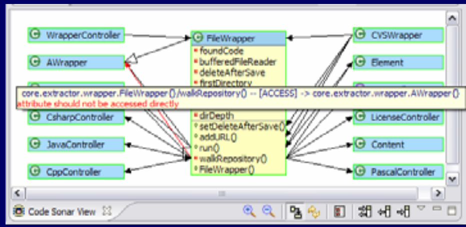


Advances in Information Visualization

- Increasing use of modern Computer Graphics technologies
- New visualization techniques
- New interaction metaphors
- Merging of techniques from all visualization research fields

Software/Algorithm Visualization

- Used to visualize information about software systems (algorithms) based on their structure, size, history, or behavior.
- Frequently uses software metrics and information visualization techniques



1.5 Top Scientific Visualization Research Problems

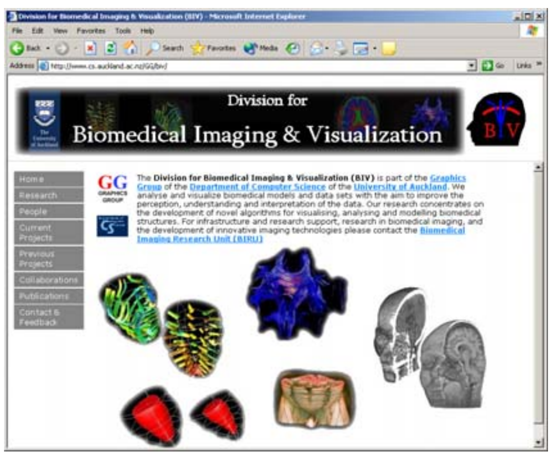
1. Think about the science
2. Quantify effectiveness
3. Represent error and uncertainty
4. Perceptual issues
5. Efficiently utilising novel hardware architectures
6. Human-computer interaction
7. Global/local visualization (details within context)

Top Scientific Visualisation Research Problems (cont'd)

8. Integrated problem-solving environments (PSEs)
9. Multifield visualization
10. Integrating scientific and information visualization
11. Feature detection
12. Time-dependent visualization
13. Scaleable, distributed, and grid-based visualization
14. Visual abstractions
15. Theory of visualization

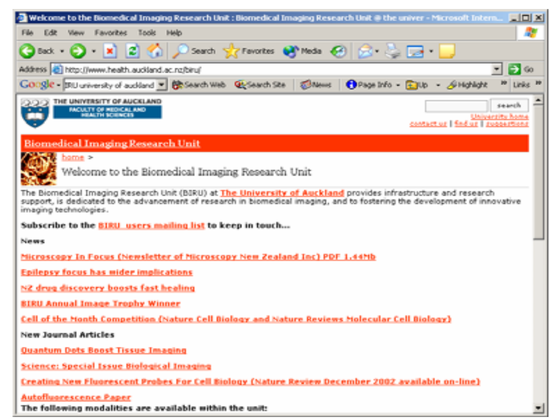
1.6 Visualization at the University of Auckland

- Division for Biomedical Imaging and Visualization (BIV)
- Research
  - Biomedical Visualization
  - Analysis, classification and reconstruction of biomedical data
  - Modelling
  - Telemedicine



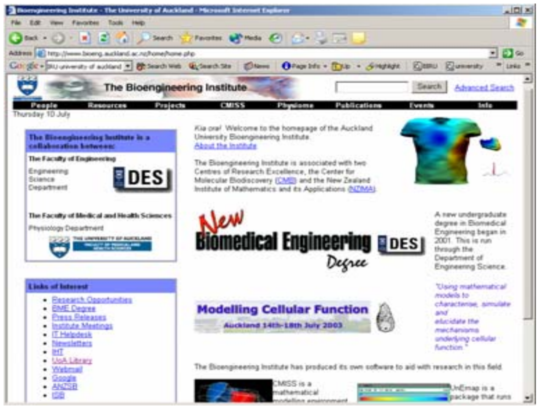
Visualization at the University of Auckland (cont'd)

- Biomedical Imaging Research Unit (BIRU)
- Research
  - Biomedical Imaging
  - Image Analysis
  - Biomedical Modelling

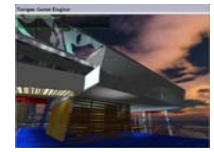


Visualization at the University of Auckland (cont'd)

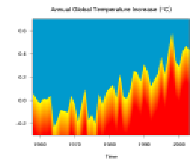
- Bioengineering Institute
- Research
  - Development of anatomically and biophysically based mathematical models of all aspects of the human physiology.



Visualization at the University of Auckland (cont'd)



- School of Architecture
  - Collaborative Virtual Environments for education and research (CVE)
- Various people in the Software Engineering Program
  - Software Visualization



- Ross Itaka (Statistics)
  - Information Visualization
- Gordon Mallinson (Mechnical Engineering)
  - Computational fluid dynamics and visualization.