Immersive Visual Data Analysis

Oliver Kreylos

W.M. Keck Center for Active Visualization in the Earth Sciences (KeckCAVES)

University of California, Davis
KeckCAVES

- Interdisciplinary research project
  - Computer science
  - Physical sciences
  - Faculty, post-docs, graduate/undergraduate students

- Develops virtual reality (VR) for scientific data analysis
  - Methods, software, systems

- Visualization facility
  - Shared access to high-end visualization systems
Principles of Scientific Visualization
Modern science is in the business of creating, processing, and consuming massive amounts of data.

Data sizes are driven by high-resolution sensors and high-performance computing.

Example: Computational Fluid Dynamics (CFD)

A single wind tunnel simulation can create petabytes of data.
CFD: Cow at Mach 8

(from http://blogs.mentor.com/robinbornoff/blog/)
End product of science is **insight**, not **data**.

Scientific process turns data into insight:

- Data analysis usually a multi-step pipeline
- Data analysis is often manual
“At their best, graphics are instruments for reasoning about quantitative information. Often the most effective way to describe, explore, and summarize a set of numbers – even a very large set – is to look at pictures of those numbers.”

CFD: Cow at Mach 8

(from http://blogs.mentor.com/robinbornoff/blog/)
Classes of Data

- Two classes of scientific data:
  - Non-spatial
  - Spatial
  - Gene co-expression networks
  - Air flow around a cow
  - Important sub-class:
    - Three-dimensional spatial
  - 3D spatial data is problematic for traditional visualization
  - Traditional displays are two-dimensional
3D Visualization in 2D

- Displaying 3D data in 2D requires projection
- Projection distorts...
  - relative positions
  - distances and sizes
  - angles
  - areas and volumes
- Projection can hide important structure
Projection Distortion
Projection Distortion

Not parallel
Projection Distortion

Not same length
Projection Distortion

Not a right angle
Projection Distortion

Ceci n'est pas un cube
2D Visualization

- Projection can also create spurious structure

(from http://moillusions.com)
3D Visualization in VR

- VR is a display medium for 3D content
- VR presents 3D objects without projection:
  - No distortion of positions, distances, angles, areas, or volumes
  - No hidden or spurious structures
- VR is "holographic"
- VR lets users apply their full power of visual perception to 3D data analysis
Principles of Virtual Reality
Vision
Vision
Vision
Vision
Vision
Vision
Vision
Movement
Movement
Movement
Movement
Movement
Movement
Movement
Modern VR
Head-mounted Displays
Head-mounted Displays
Head-mounted Displays
Interactive Visualization
Static Visualization

Parameters

Data → Visualization → Picture
Interaction in VR

- VR is particularly good medium for interaction:
  - “Holographic” 3D display
  - Direct natural 3D interaction
- Hand-held 3D input devices
- Real-time feedback
Immersive Visual Data Analysis
LiDAR Viewer
Tele-Collaboration
3D Video Avatars
KeckCAVES
Software
KeckCAVES Software

- All KeckCAVES software is publicly available
- Free and open-source (GNU GPL)
- Runs primarily on Linux, also on Mac OS X
- http://keckcaves.org
Vrui VR Toolkit

- Foundation for everything else
- Lets VR software run on wide range of hardware
  - Laptop or desktop
  - 3D TVs
  - Projected 3D screens
  - CAVEs et al.
  - Head-mounted displays
LiDAR Viewer

- Analysis of massive 3D point cloud data
3D Visualizer

- Analysis of 3D gridded volumetric data
Nanotech Construction Kit

- Interactive creation of molecular structures
Tele-Collaboration

- Vrui add-on to connect multiple VR systems

3D Video Avatars

- Capture, transmit, and play 3D video
VR Hardware

- Good VR hardware has hit the mass market
- Head-mounted displays:
  - Oculus Rift
  - HTC Vive
- Works natively with Vrui
- Easy to buy
  - Best Buy, Amazon, newegg
- Easy to set up
- VR no longer limited to central facilities
Conclusions

- VR is a powerful medium for analysis of 3D spatial scientific data
  - Presents 3D data in “holographic” 3D
  - Supports natural 3D interaction
  - Supports natural collaboration
- KeckCAVES software is publicly available
  - Free and open-source software (GNU GPL)
  - Runs on Linux (and also Mac OS X)
  - http://keckcaves.org
- Anyone can use VR
Demos!