NSF Grant Number: CCR-0086065 **PI:** David H. Laidlaw **Institution:** Brown University

Visualization of Multi-Valued Scientific Data: Applying Ideas from Art and Perceptual Psychology

Visualization Research Lab Brown University

Research Objectives

Generalizable and effective visual representations for 3D, multi-valued scientific data

Well-tested interaction metaphors applicable to multiple scientific disciplines

New methodologies for evaluating the efficacy of visual representations and interaction metaphors

An understanding of how and why the visual representations and interaction metaphors work

Insight and understanding into the relative strengths of immersive, semi-immersive, and desktop environments for interactive computing

Approach

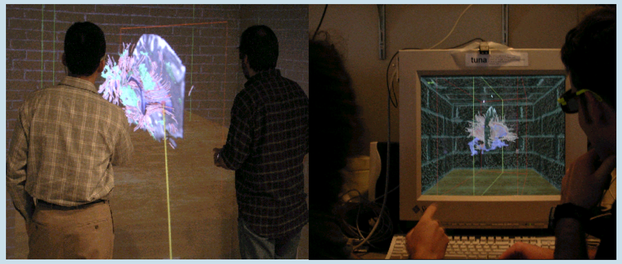
We address two types of scientific questions:

How does visualization aid knowledge discovery in our application areas?

How effective are the visualization methods themselves and can we generalize effective methods and predict the effectiveness of other methods?

While artists and perceptual psychologists provided inspiration for creating and evaluating novel visualization and interaction techniques, researchers in fluid dynamics, remote sensing, and neurobiology helped define scientific tasks of importance, assisted in the development of techniques to address these tasks, and evaluated the results. This collaboration provided unique opportunities to validate our new techniques and ensure that they were responsive in addressing the domain-specific scientific problems.

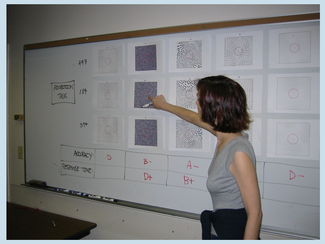
Selected Results



Fish Tank VR systems are better than CAVE systems

We found that scientific users performing hypothesis-driven tasks preferred using a desktop-based virtual reality system to an immersive system.

In a quantitative user study using a generic visual search task, users performed faster and more accurately using the desktop-based VR system. We also found that visual context did not influence user behavior. [IEEE Visualization 2002, 2003 Posters]



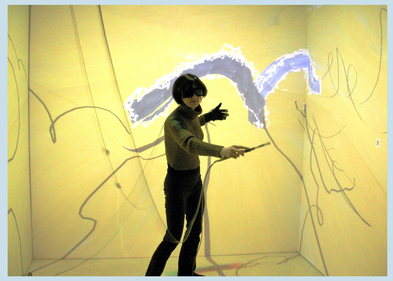
Visual designers are as good as a traditional user study

In evaluating the effectiveness of 2D vector visualization methods, designer critiques provided similar information to the results of a traditional computer-based user study.

Additionally, designers provided methods for improving the visualizations to increase the efficacy of the techniques; this information is difficult to glean from the results of a traditional user study. [SIGGRAPH'03 Sketch]

2D vector visualization methods vary in efficacy

We characterize differences among six methods. [Visualization'01 Poster, TVCG'04, in press]



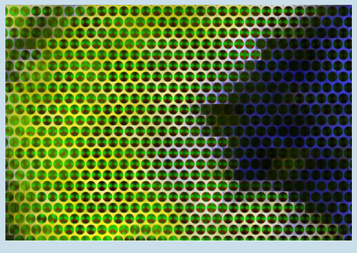
New tools are needed for effective participation of visual design experts.

Our CavePainting application serves as a testbed and development platform for novel interaction and visual representation methods and allows a designer to sketch in 3D to help conceptualize different scientific visualization models.

The model above shows a conceptual scheme for visualizing bat flight created using CavePainting. The figure just behind the user represents the bat wings and extended lines show flight flow lines. [SIGGRAPH'03 Sketch] [Visualization'03 Poster] [ACM I3D Graphics, 2001]

Selected Tools

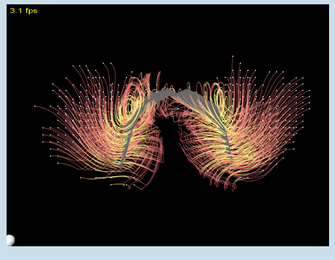
Satellite Remote Sensing



An icon-based visualization method for polarimetric radar data.

The region shown covers an area of reeds at the edge of a lake. Note the lack of rotational symmetry in many of the icons left of center - this indicates some preferential orientation in the response from the target area for different handedness of polarization. [IJRM 24(6) 2003] [IEEE IGARSS, 2002]

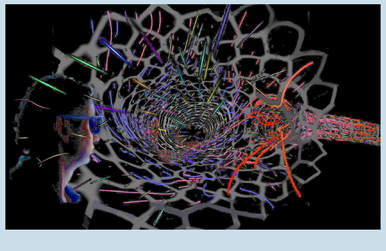
Bat Flight Dynamics



A 3D virtual reality visualization tool for studying fluid flow around a flying bat.

This tool provides easy identification of the vortices around the wing as well as wake structures, both of which is help in understanding bat flight aerodynamics. Yellow streamlines indicate low λ_2 regions, red streamlines indicate higher λ_2 regions, and the white dots are the streamline seed points. [Master's theses, 2002, 2003] [IEEE CG&A 24(2) 2004] [Siggraph'04 Poster]

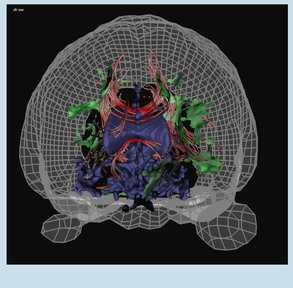
Cardiovascular Hemodynamics



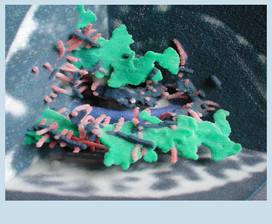
A 3D virtual reality visualization tool for investigating arterial blood flow.

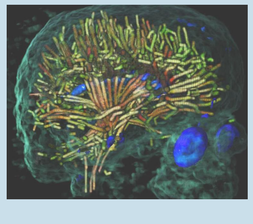
This view shows the user observing flow just upstream of a bifurcation as thousands of haloed, motion-blurred particles advecting as well as shifts in "kelp" anchored to the walls. The chicken-wire mesh walls reveal the vessel's structure while providing an unobtrusive spatial reference to the user. [Proc. WCMPBE, 2003] [J. Biomechanics, 2004, in review]

Brain Diffusion Tensor Imaging



Several 3D visualization tools for showing white matter tracks using brain diffusion tensor imaging (DTI).





The gray mesh gives a spatial reference for overall brain structure. The red streamtubes and green streamsurfaces show linear and planar anisotropy respectively. The blue areas indicate anatomical landmarks for context. Display is possible in a variety of display environments. [MRM 51(1) 2004] [TVCG 2004] [MICCAI 2004] [TVCG 9(4) 2003]

Broader Impact

Information Technology:

Our new methods help scientists in many disciplines to more effectively interact with their data and accelerate their science

Our interaction and visualization techniques will become more broadly accessible as the computational environments we use are more widely available

Our approach to training future scientists in collaborating outside their core disciplines ensures a continuous exchange of ideas leading to more healthy research

Scientific Application Domains:

Our research of blood flow will lead to improved understanding of and treatment for cardiovascular pathologies

Our advances in remote sensing will provide more effective resource monitoring leading to widespread improvements in global quality of life

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