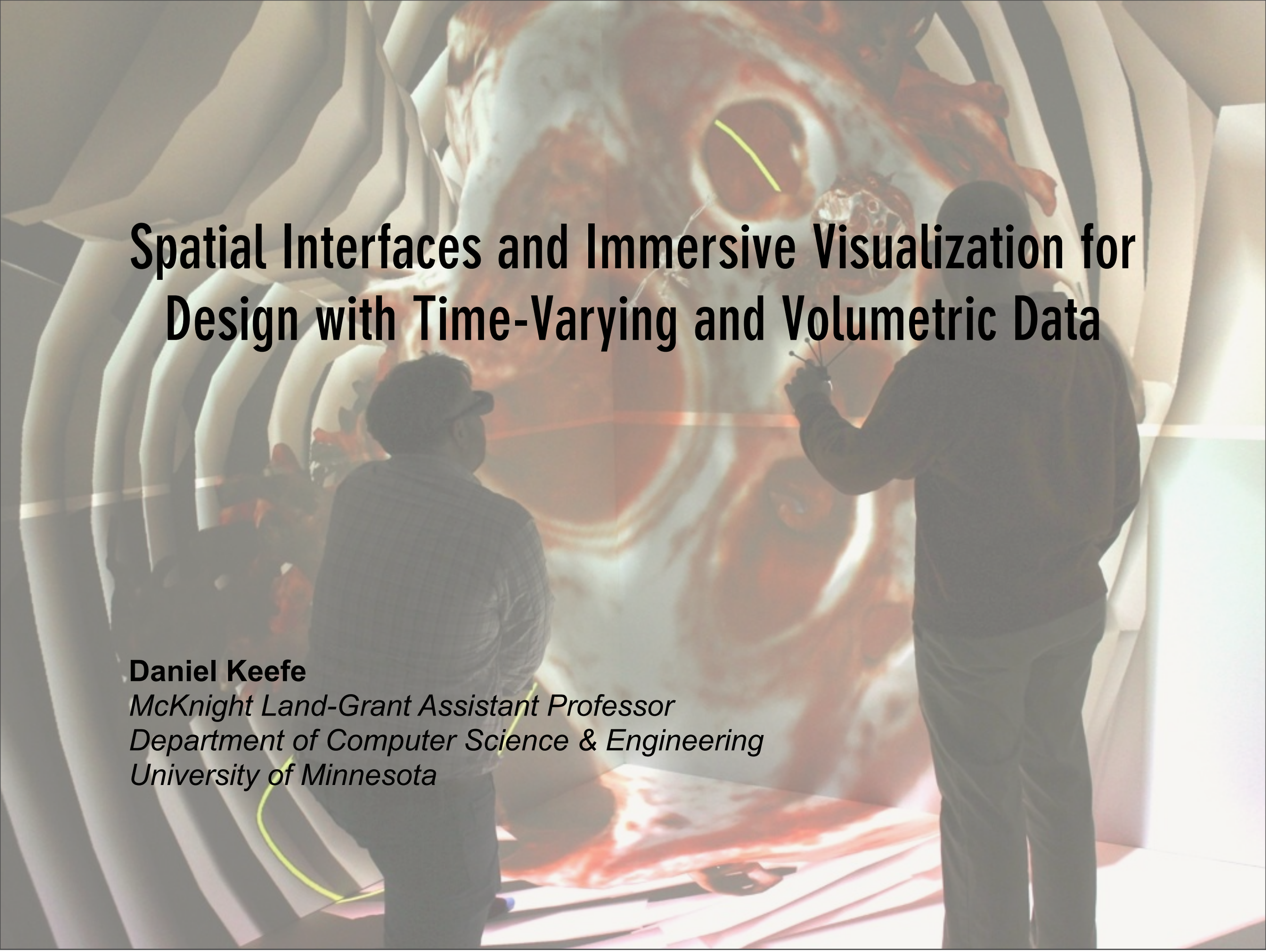
Use of Interactive Supercomputing and Virtual Environments for the Design, Verification, and Manufacture of Medical Devices

Arthur Erdman
Medical Devices Center, University of Minnesota

Daniel Keefe
Department of Computer Science & Engineering, University of Minnesota

Randy Schiestl
Boston Scientific



Spatial Interfaces and Immersive Visualization for Design with Time-Varying and Volumetric Data

Daniel Keefe
McKnight Land-Grant Assistant Professor
Department of Computer Science & Engineering
University of Minnesota

http://ivlab.cs.umn.edu

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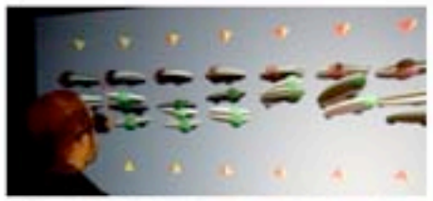
Research Projects

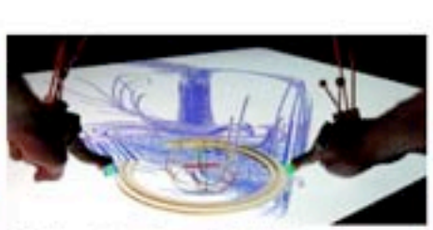


NSF CAREER: Visualizing Scientific Motions

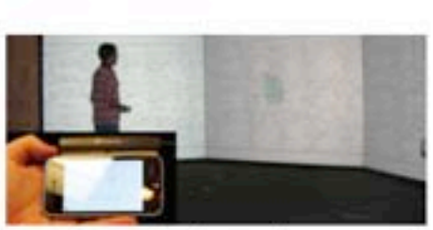
National Academies / Keck Foundation: Intelligent Interactive Imaging (3I)

Art and Design in Visualization

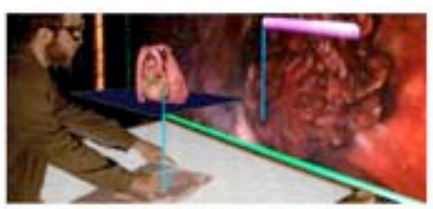
3D Modeling, CavePainting, and Drawing on Air



3D User Interfaces (Multi-Touch, Haptics, Virtual Reality)



Next Generation Immersive Visualization Environments

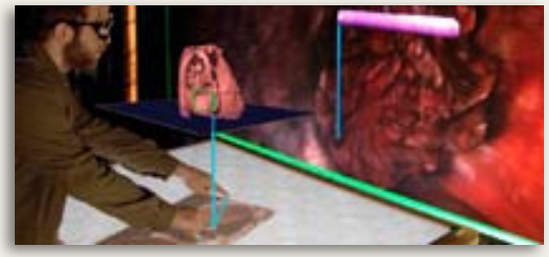


Virtual Prototyping of Medical Devices

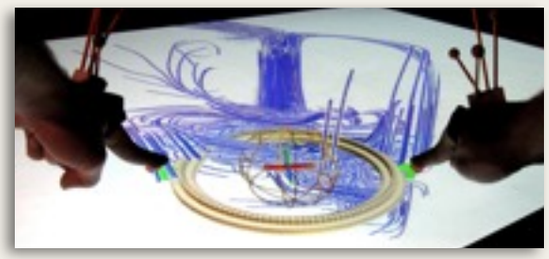
Virtual Classics

Data-Driven Surgical Training

Roadmap



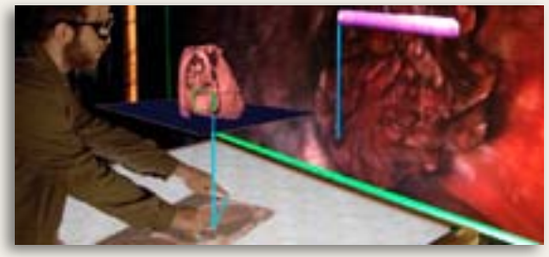
Interactive Design Platform and Virtual Prototyping



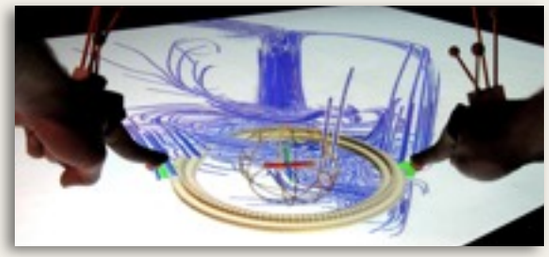
3D Modeling and Annotation in Virtual Environments

Natural Computing Interfaces for Working with Data

Roadmap



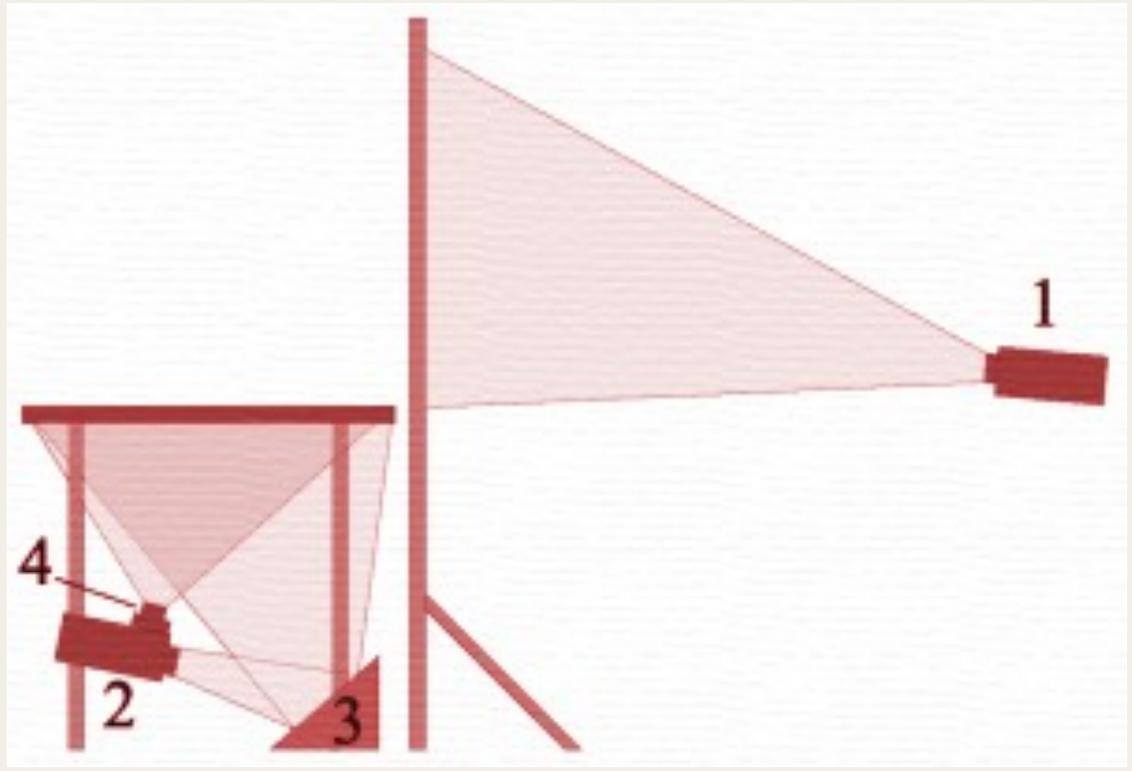
Interactive Design Platform and Virtual Prototyping



3D Modeling and Annotation in Virtual Environments

Natural Computing Interfaces for Working with Data

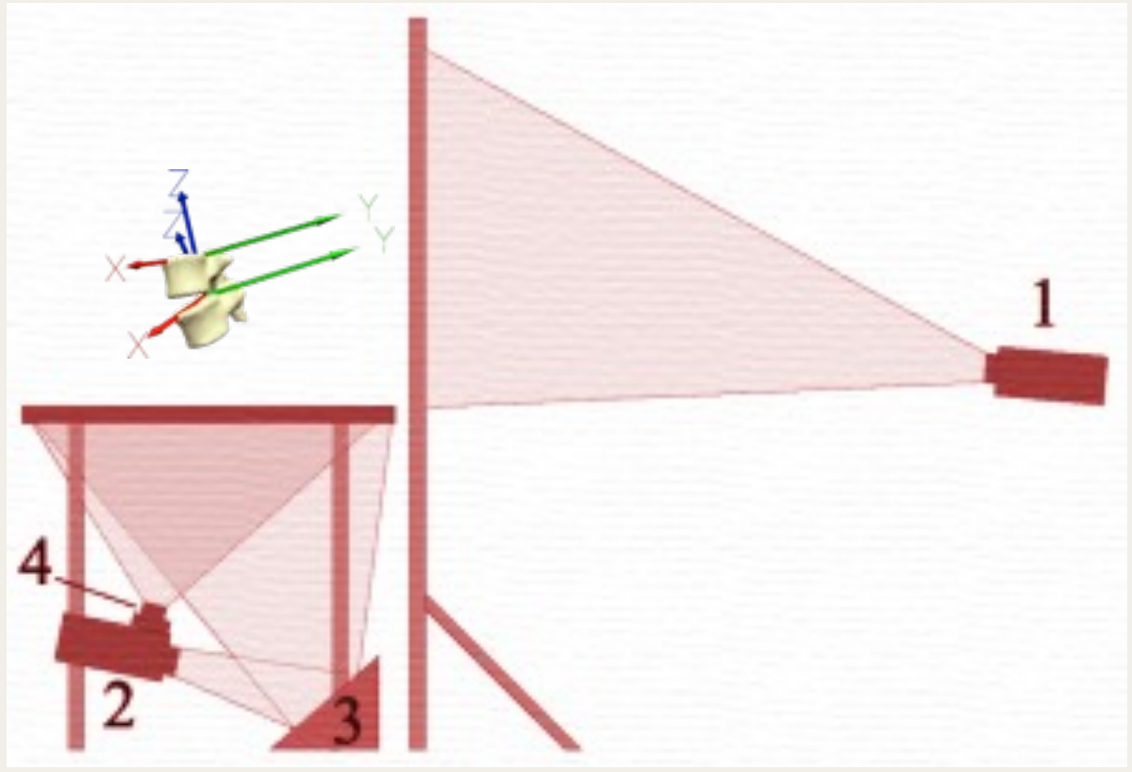
Hardware and Software for Exploratory Data Visualization



Coffey et al., Low Cost VR Meets Low Cost Multi-touch. In Proceedings of International Symposium on Visual Computing, Springer LNCS 6453, pages 351–360, 2010.

- 2 display surfaces (wall + table)
- FTIR multi-touch table
- Head-tracked stereoscopic wall

Hardware and Software for Exploratory Data Visualization



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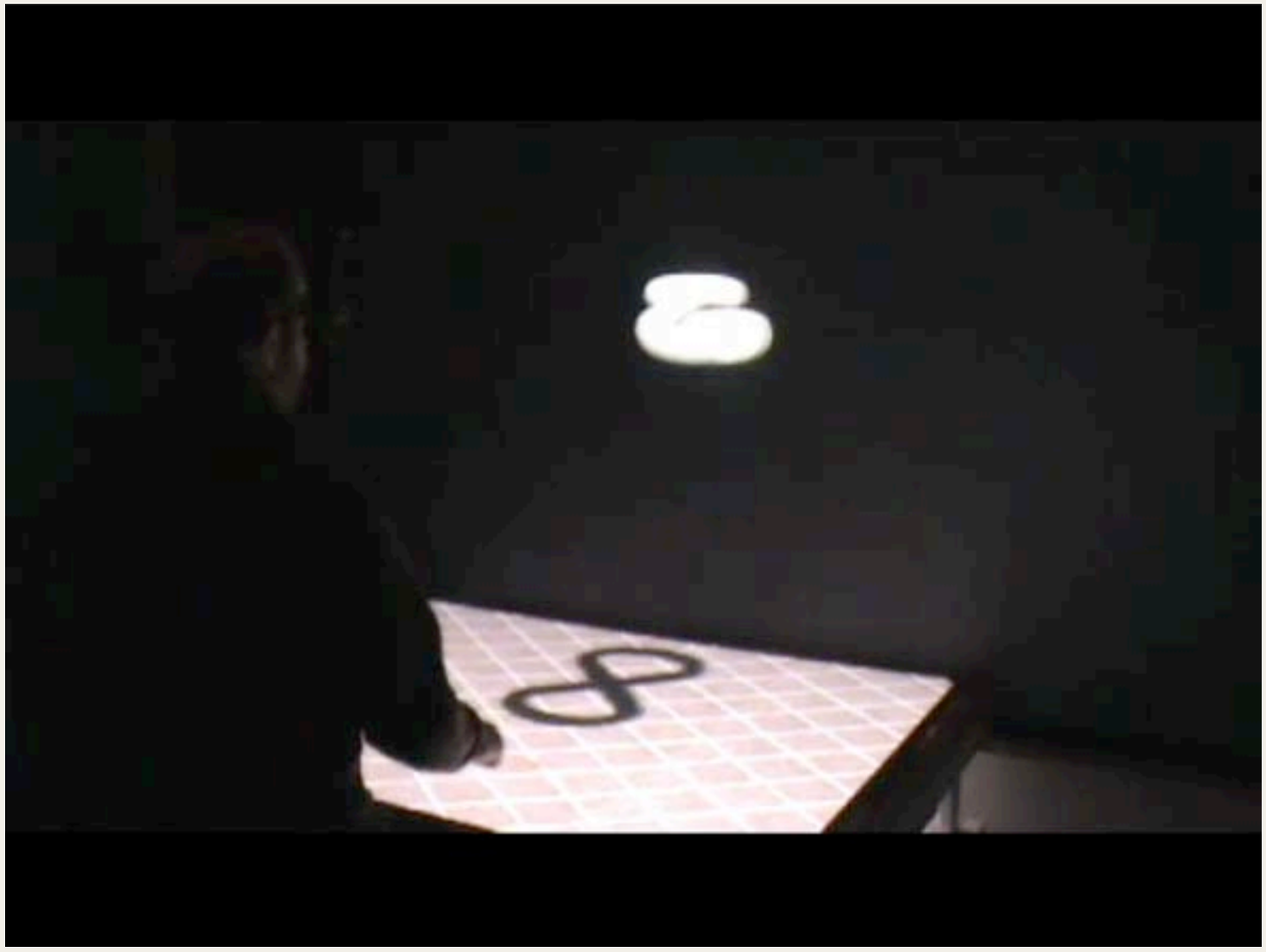
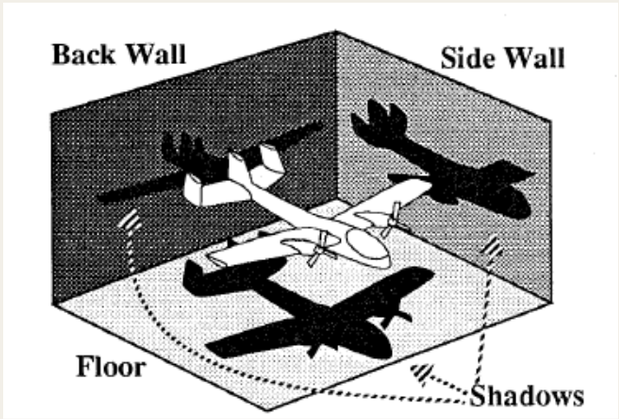
- 2 display surfaces (wall + table)
- FTIR multi-touch table
- Head-tracked stereoscopic wall

Multi-Touch Interactive Shadow Metaphor

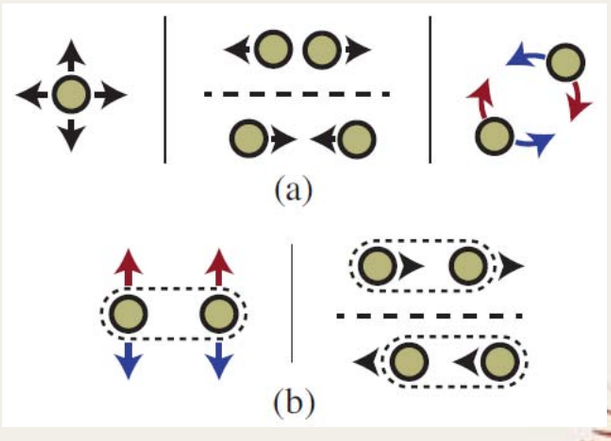


Inspiration:

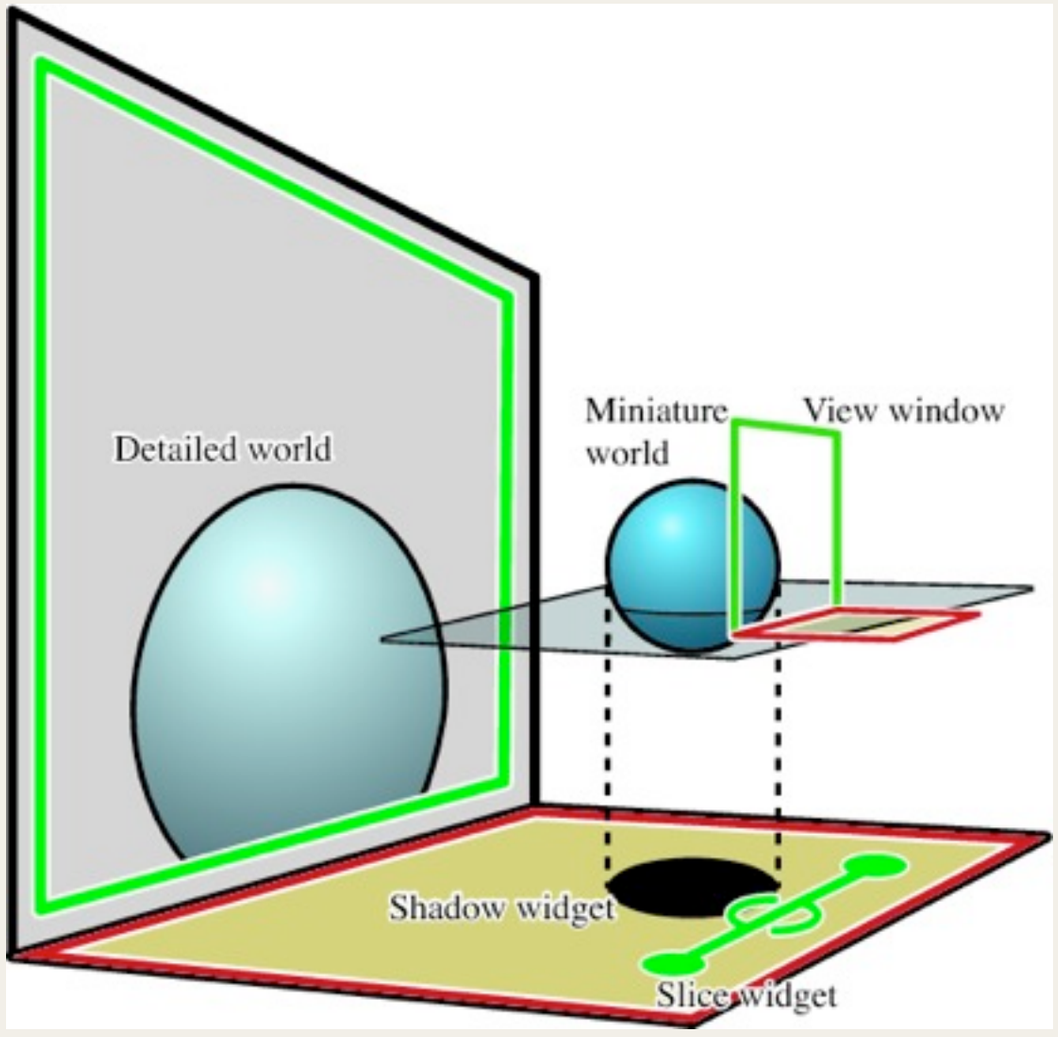
Interactive Shadows
Herndon et al. 1992



Multi-touch gestures
(a) trans, rot, scale parallel to table
(b) pitch, roll out of plane

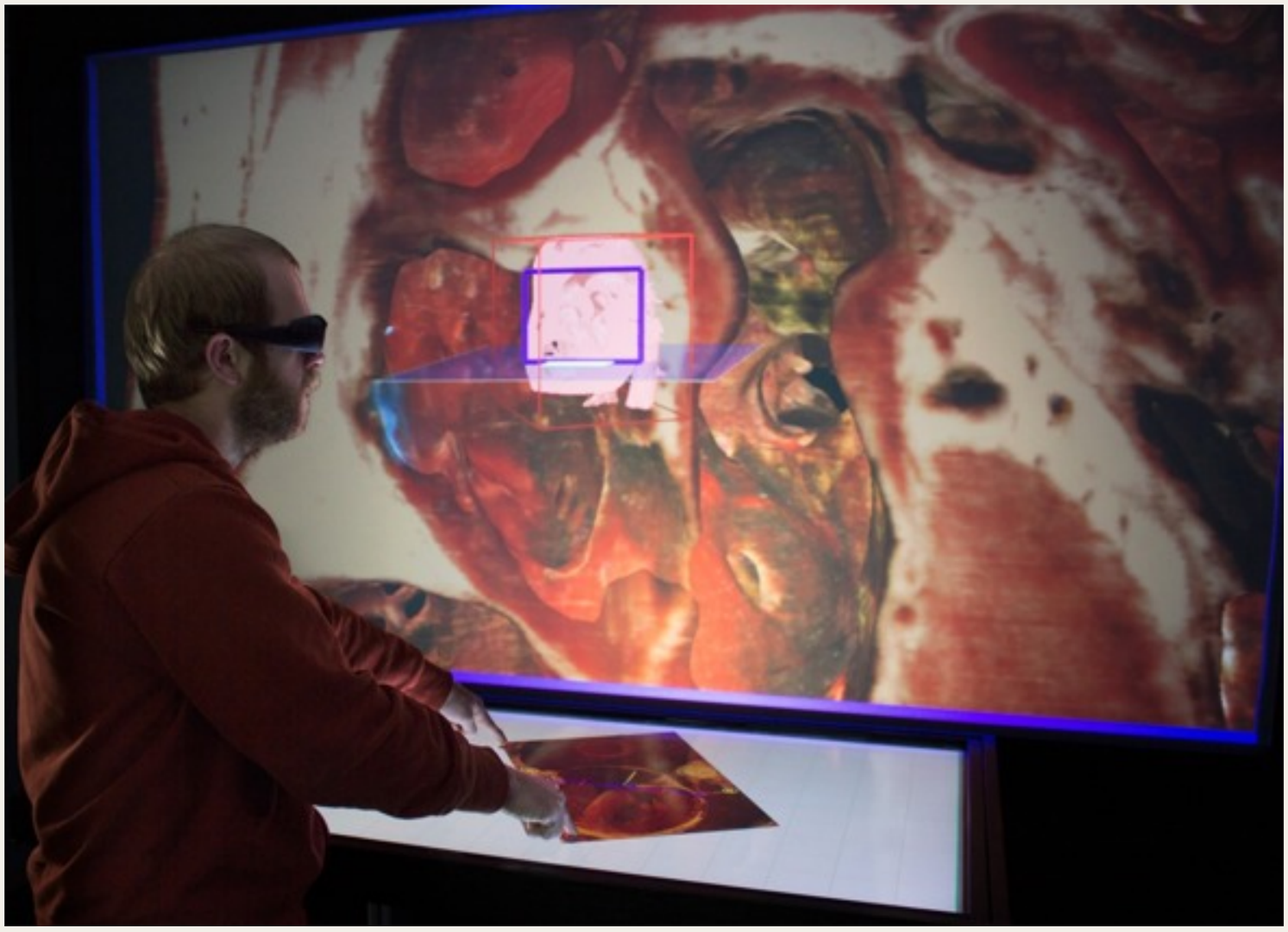


Now for More Complex Visualizations: World-in-Miniature Metaphor for 3D Touch Interfaces



Coffey et al., SliceWIM: A Multi-Surface, Multi-Touch Interface for Overview+Detail Exploration of Volume Datasets in Virtual Reality. Proceedings of ACM Symposium on Interactive 3D Graphics and Games *2011*, pages 191-198, 2011.
Best Paper Award (honorable mention)

Now for More Complex Visualizations: World-in-Miniature Metaphor for 3D Touch Interfaces

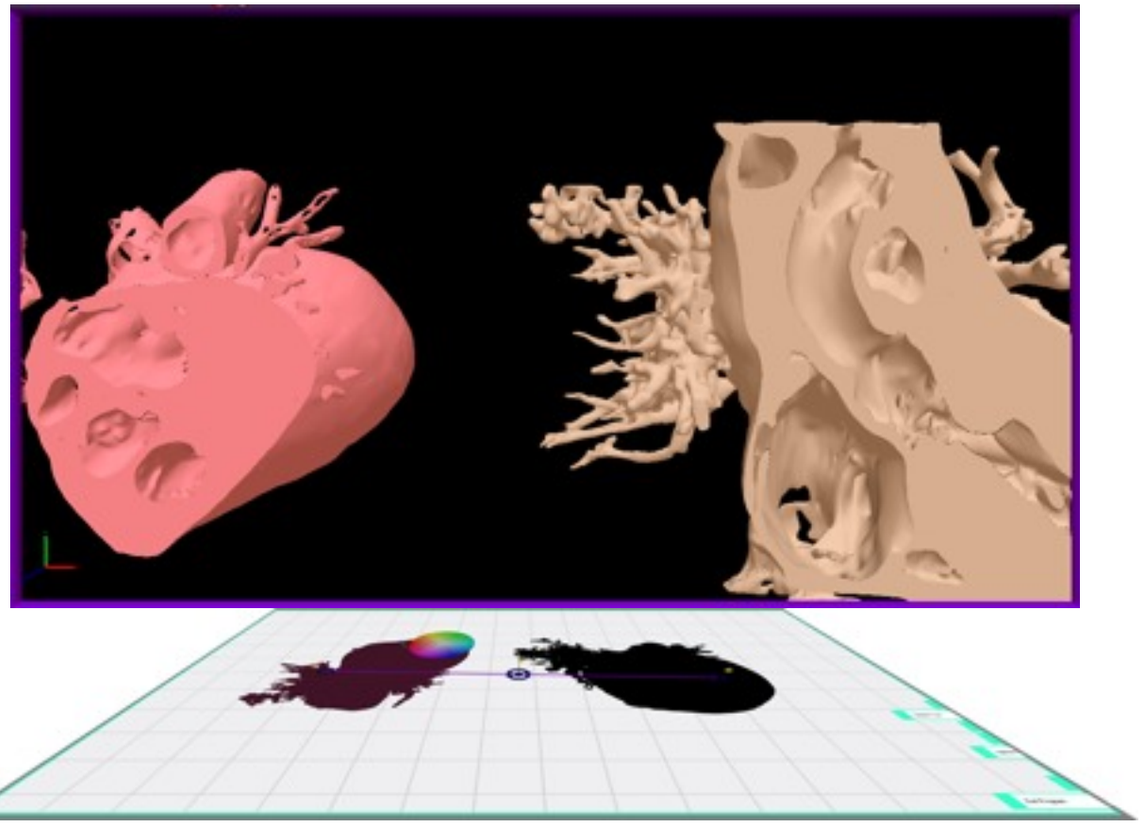


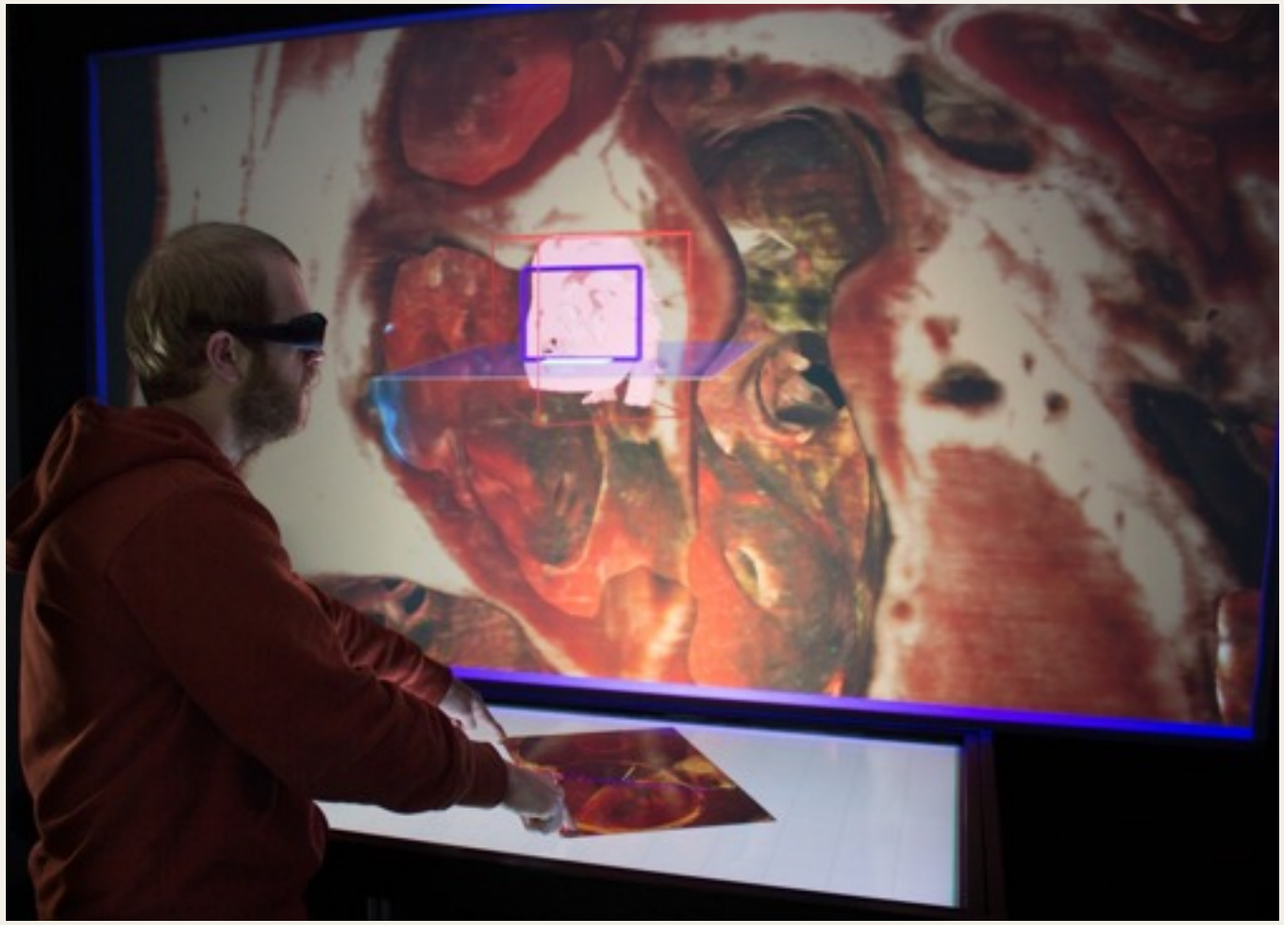
Coffey et al., Interactive SliceWIM: Navigating and Interrogating Volume Datasets Using a Multi-Surface, Multi-Touch VR interface. IEEE Transactions on Visualization and Computer Graphics, 2012.

Data: National Library of Medicine, Visible Human Project: http://www.nlm.nih.gov/research/visible/visible_human.html


3D Floating Miniature

Why mix 2D and 3D?





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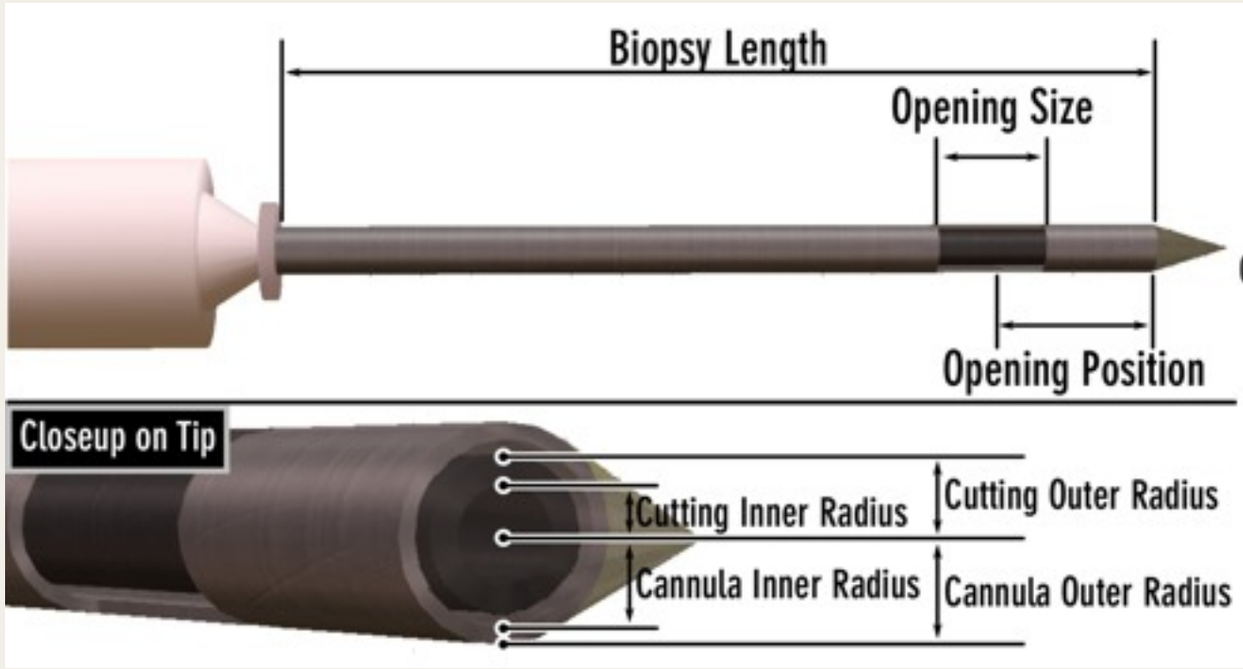
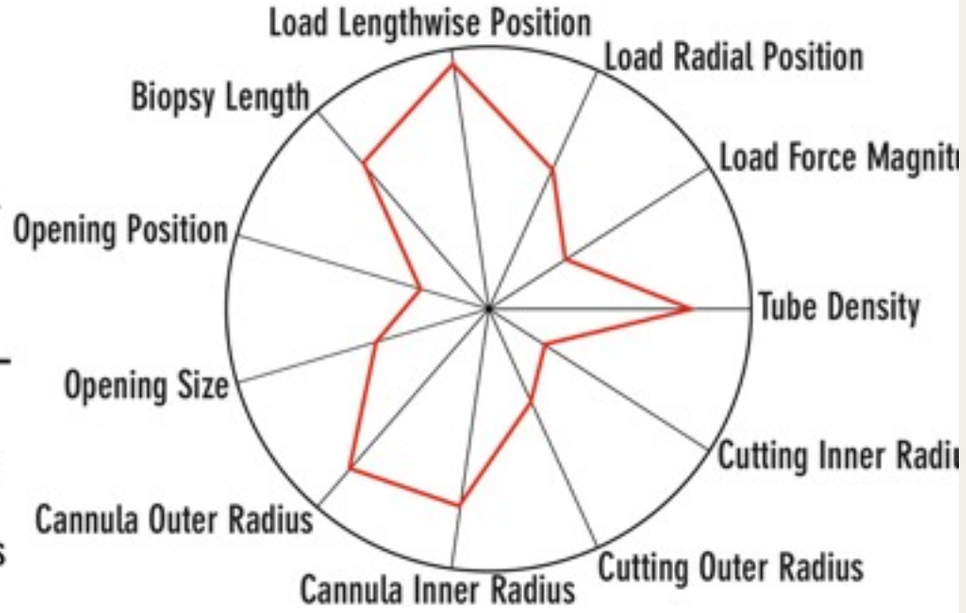
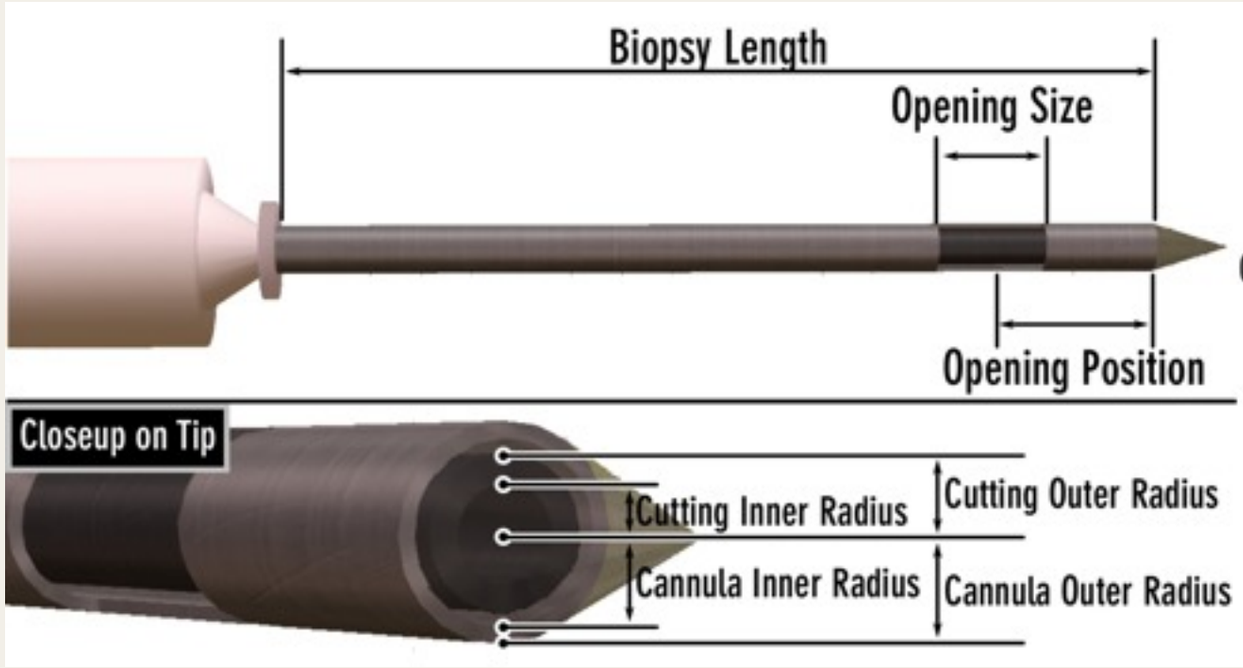
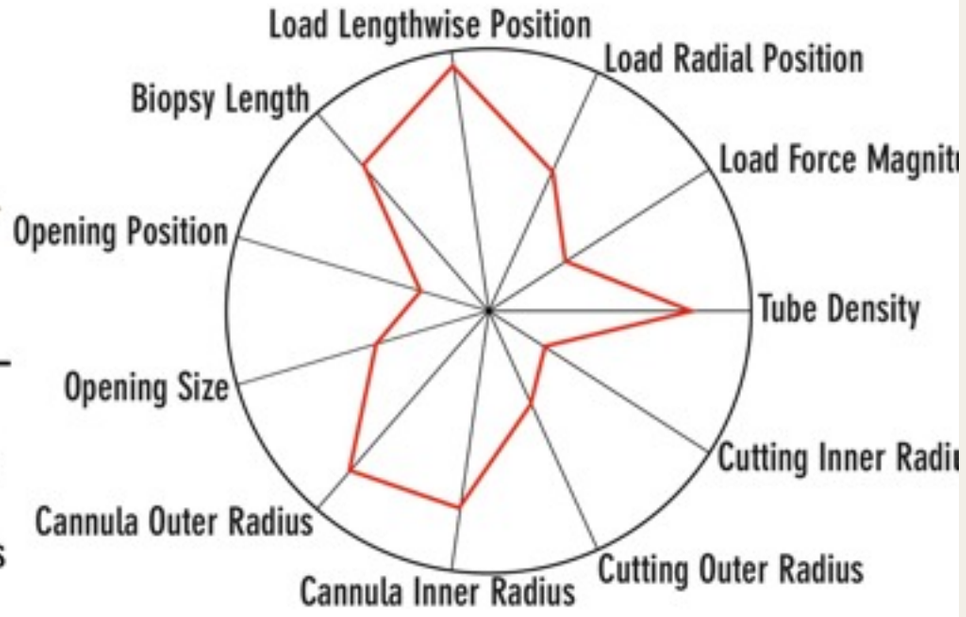
Supporting Device Design Workflows

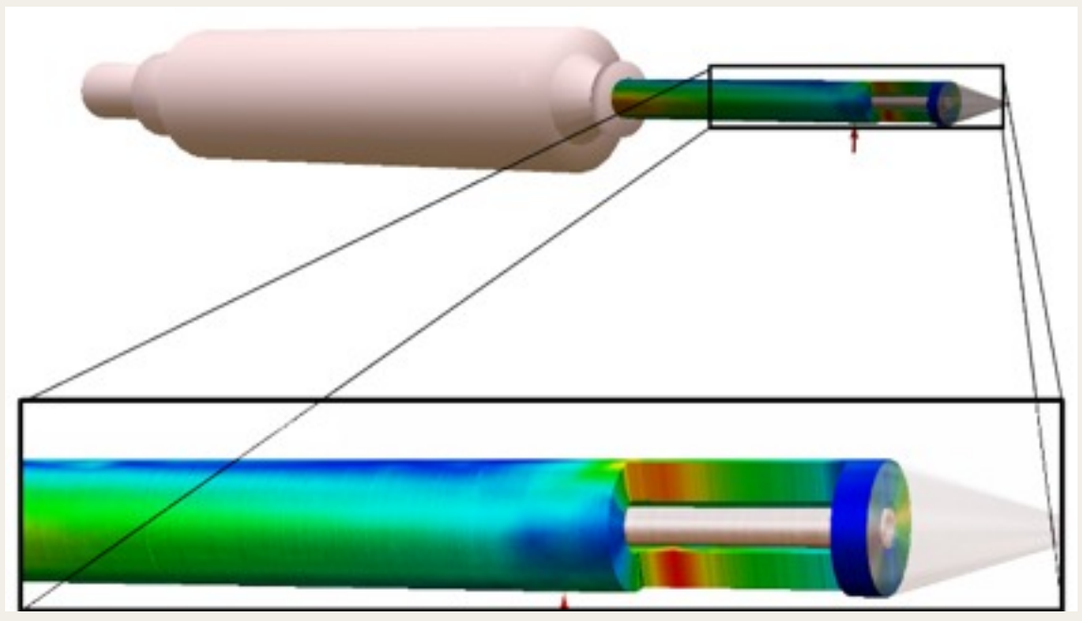


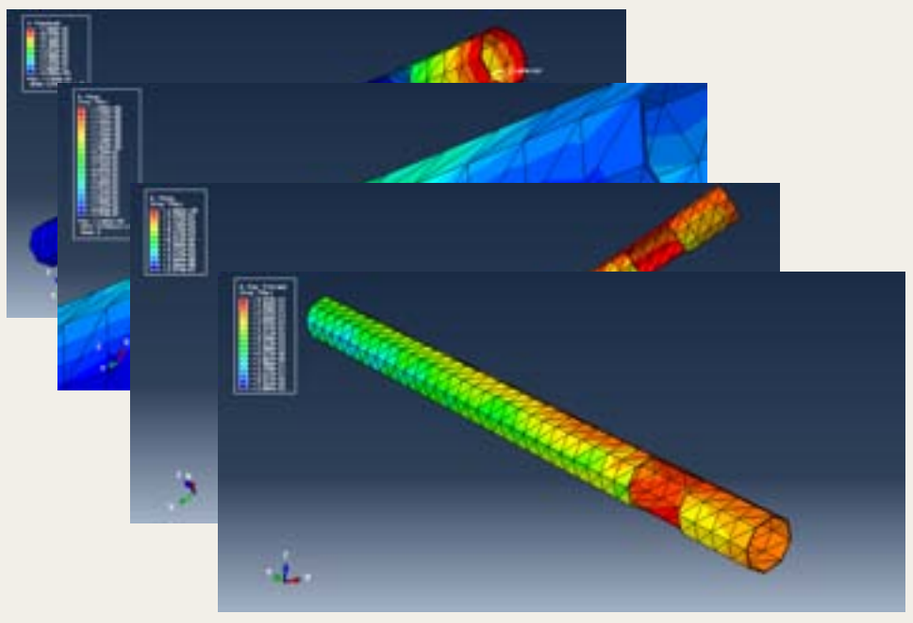


Supporting Device Design Workflows



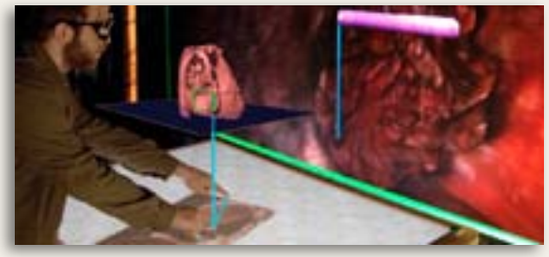




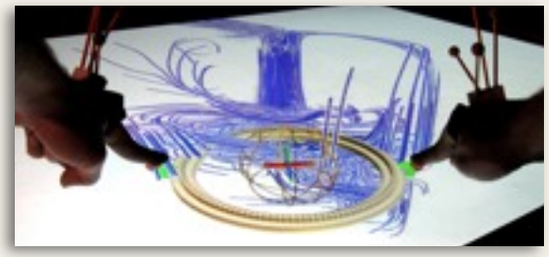


...

Roadmap



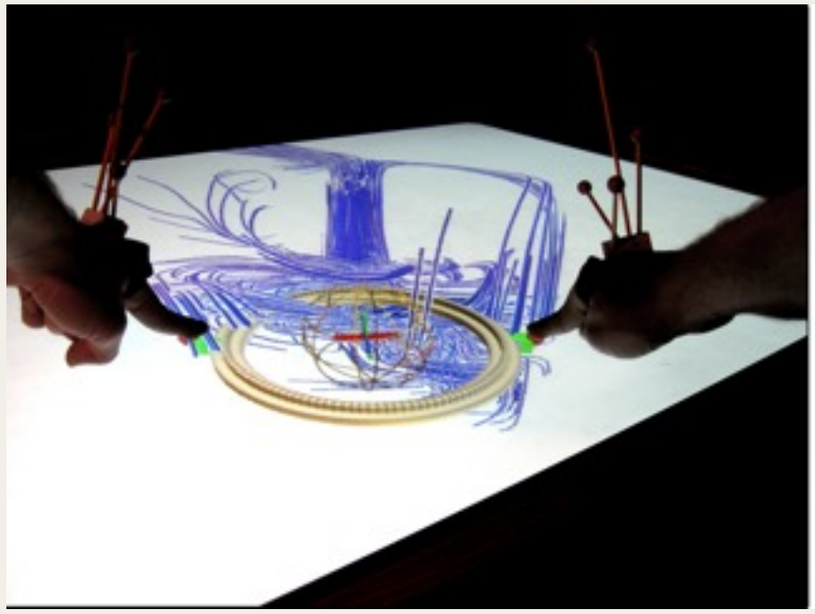
Interactive Design Platform and Virtual Prototyping

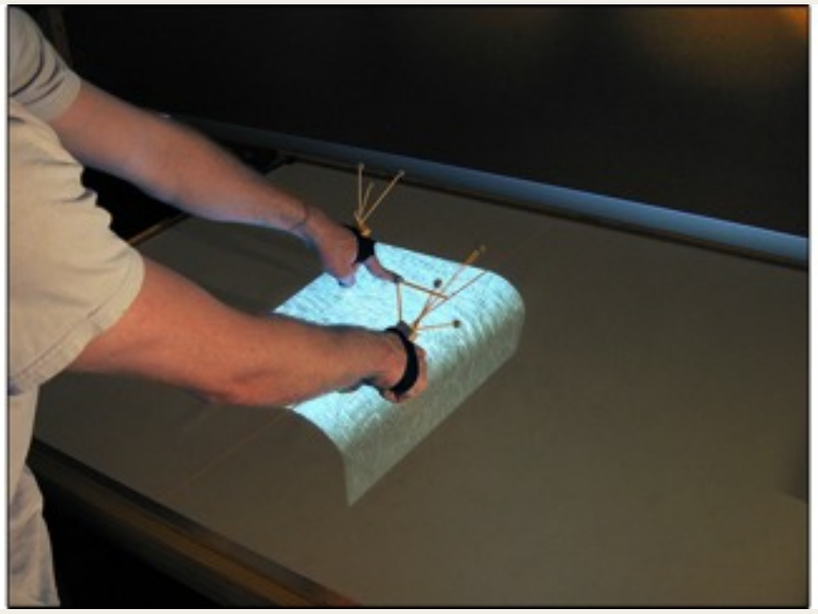


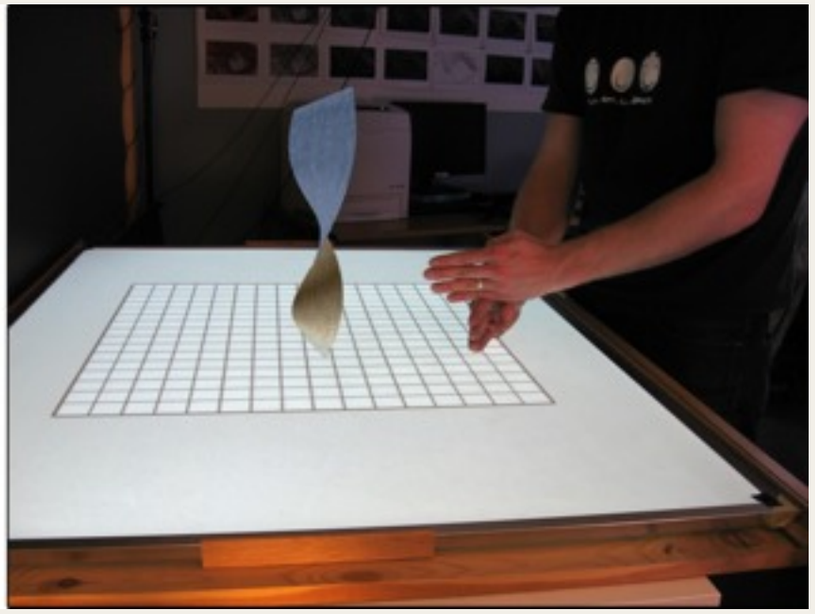
3D Modeling and Annotation in Virtual Environments

Natural Computing Interfaces for Working with Data

Can we extend natural user interfaces to the 3rd dimension? Some examples for 3D modeling tasks.

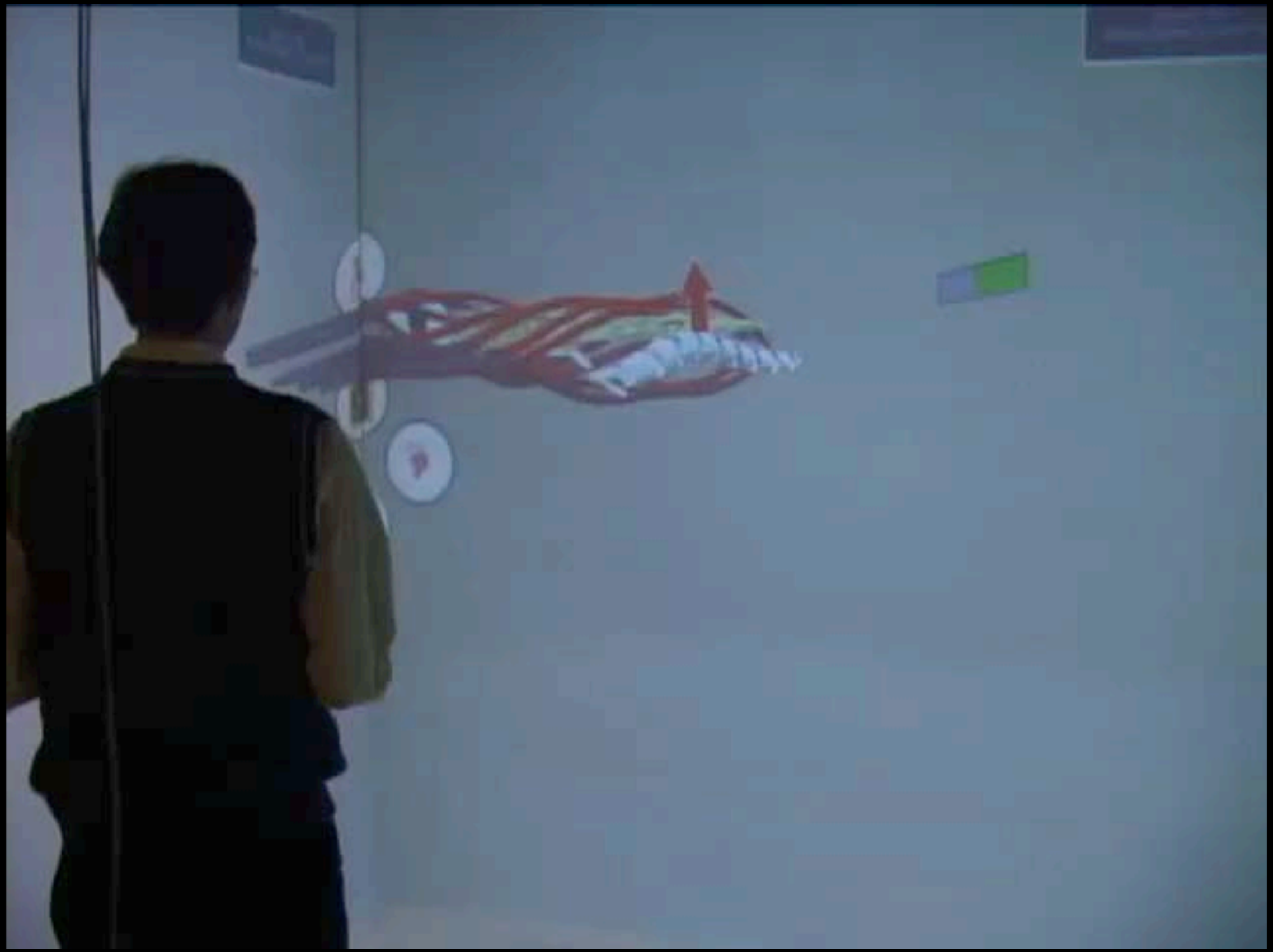






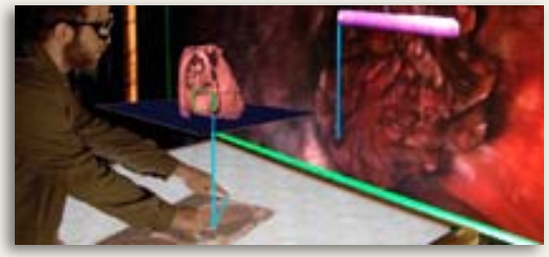
Bret Jackson, David Schroeder, and Daniel F. Keefe.
Nailing Down Multi-Touch: Anchored Above the Surface Interaction for 3D Modeling and Navigation.
Graphics Interface 2012., 2012.

Daniel F. Keefe, Robert C. Zeleznik, and David H. Laidlaw. Drawing on air: Input techniques for controlled 3D line illustration. IEEE Transactions on Visualization and Computer Graphics, 13(5): 1067–1081, 2007.

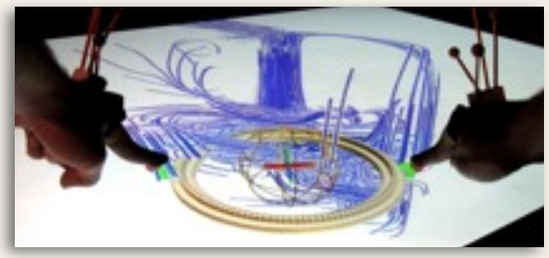


Daniel F. Keefe, Daniel Acevedo, Jadrian Miles, Fritz Drury, Sharon M. Swartz, and David H. Laidlaw. Scientific sketching for collaborative VR visualization design. IEEE Transactions on Visualization and Computer Graphics, 14(4):835–847, 2008.

Roadmap



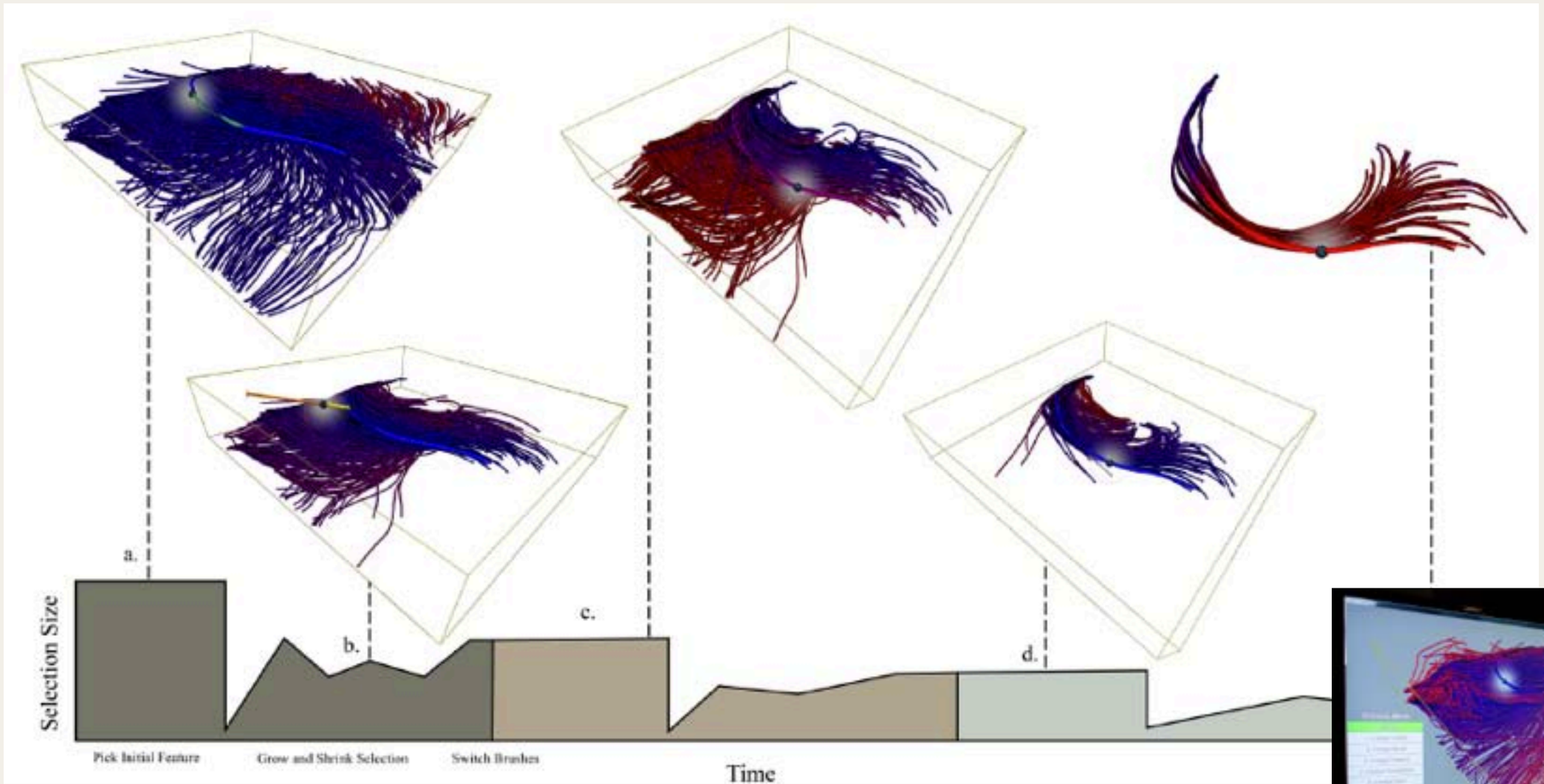
Interactive Design Platform and Virtual Prototyping



3D Modeling and Annotation in Virtual Environments

Natural Computing Interfaces for Working with Data

Controllable Multi-Variate 3D Selections Using a 3D Force Feedback Device



B. Jackson, D. Coffey, and D.F. Keefe. Force Brushes: Progressive Data-Driven Haptic Selection and Filtering for Multi-Variate Flow Visualizations. EuroVis 2012.

Hurricane Isabel data produced by the Weather Research and Forecast (WRF) model, courtesy of NCAR and the U.S. National Science Foundation (NSF).

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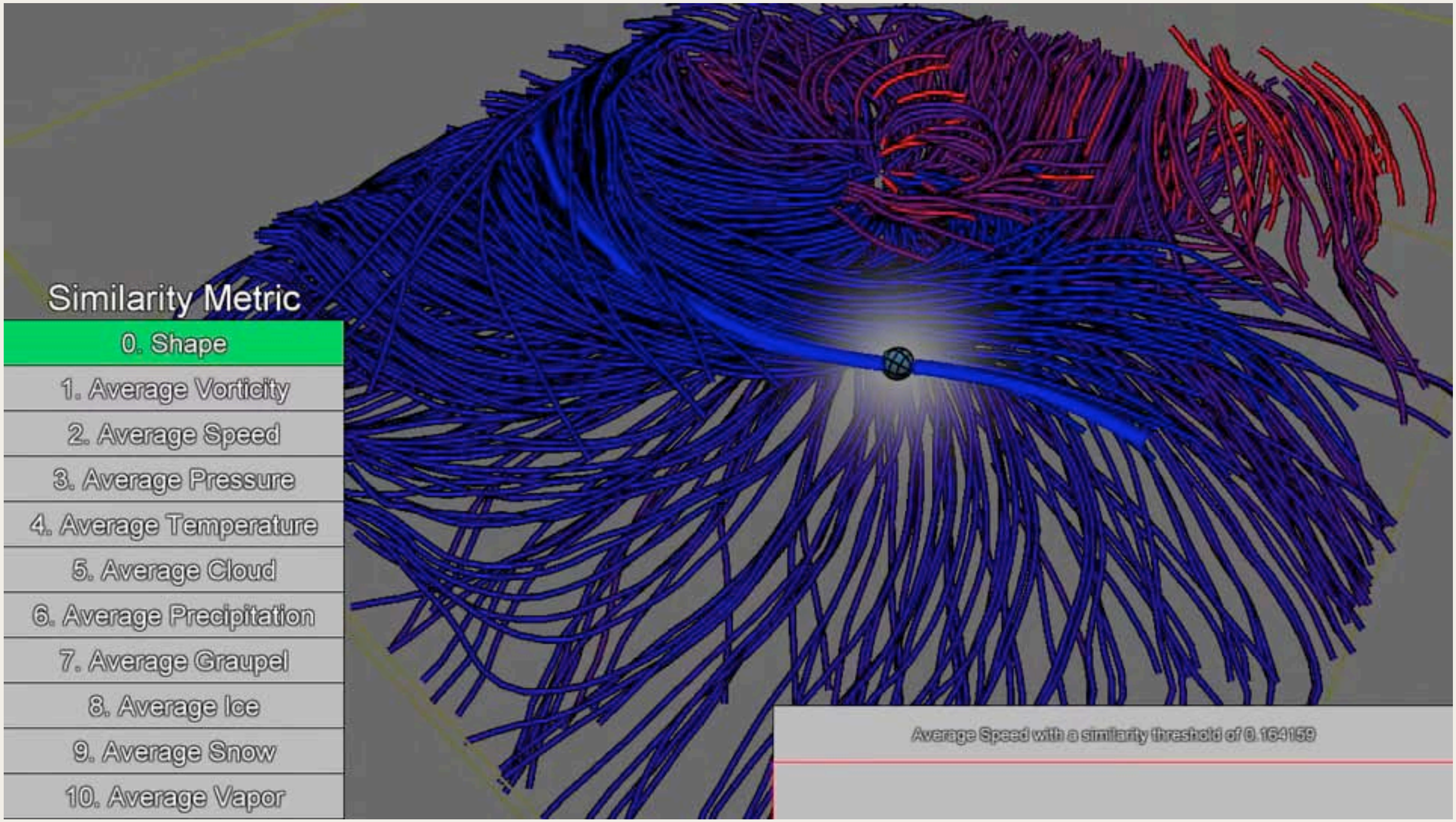
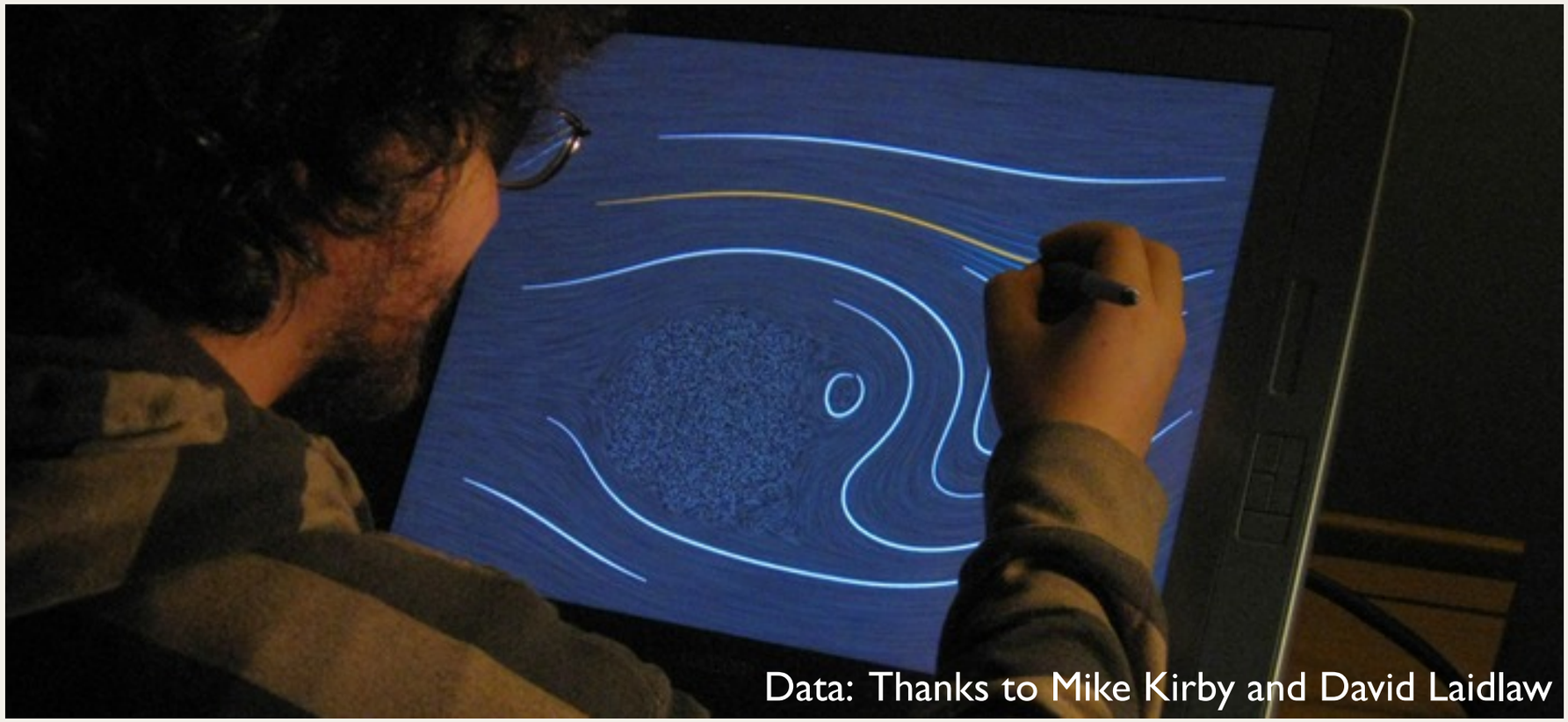

Similarity Metric
0. Shape
1. Average Vorticity
2. Average Speed
3. Average Pressure
4. Average Temperature
5. Average Cloud
6. Average Precipitation
7. Average Graupel
8. Average Ice
9. Average Snow
10. Average Vapor
Average Speed with a similarity threshold of 0.164159

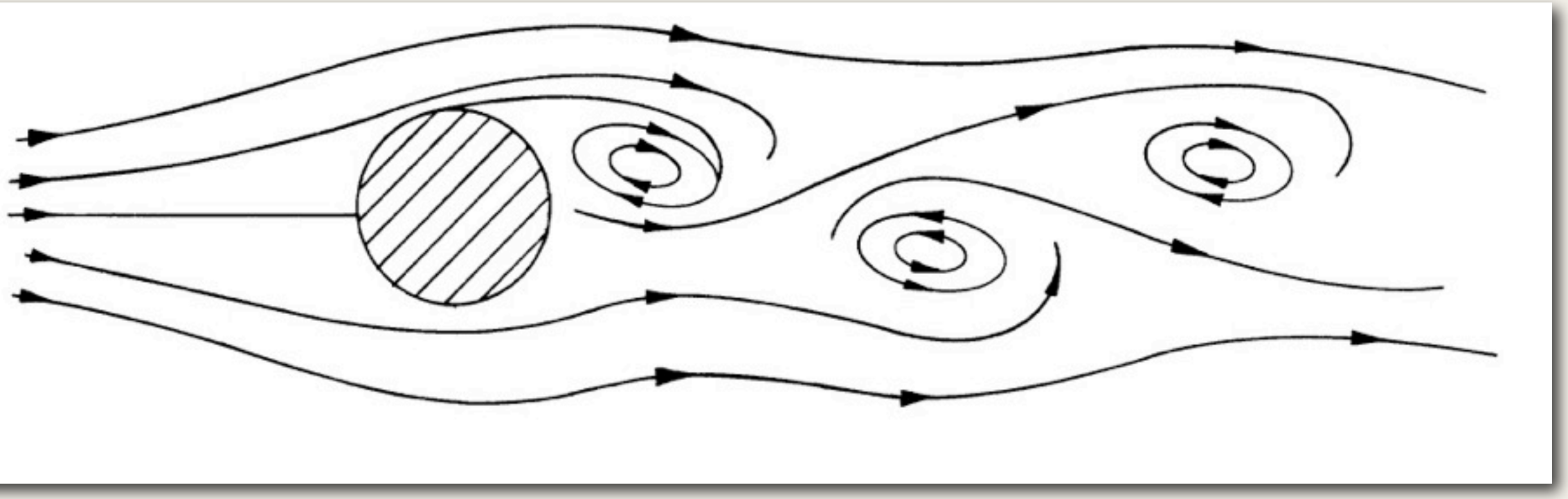
Another Example: Interactive 2D Vector Field Illustration



David Schroeder, Dane Coffey, Daniel F. Keefe. Drawing with the Flow: A Sketch-Based Interface for Illustrative Visualization of 2D Vector Fields In Proceedings of ACM SIGGRAPH/ Eurographics Sketch-Based Interfaces and Modeling 2010, 2010.

- Use hardware and metaphors familiar to designers.
- Leverage existing research in gestural user interfaces.
- Develop methods of linking input to underlying datasets.
- Use automation to simplify tedious and repetitive design tasks.

Even Within "Simple" 2D Line Drawings, Human Designers Make Informed Decisions



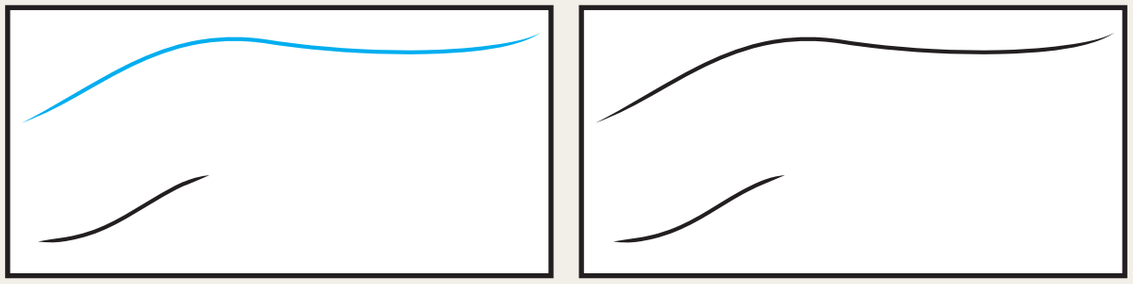
[Turk et al. SIGGRAPH 1996]

- Variable streamline density
- Streamlines seeded in specific places
- Streamlines cut short in specific places
- ...

Streamline Gesture Set

Streamline Gesture Set

New



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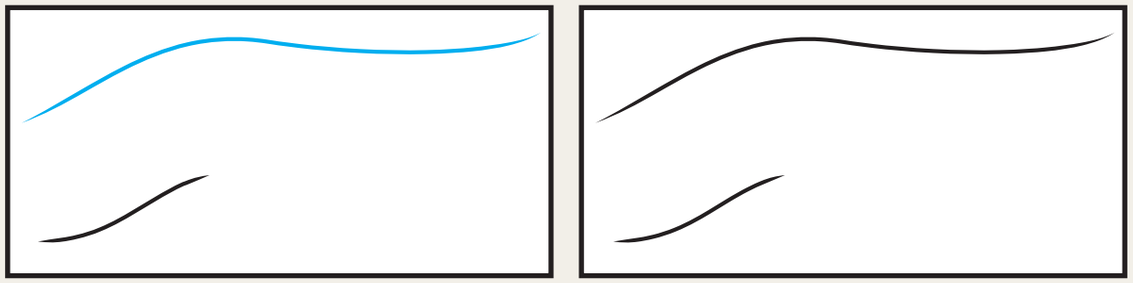
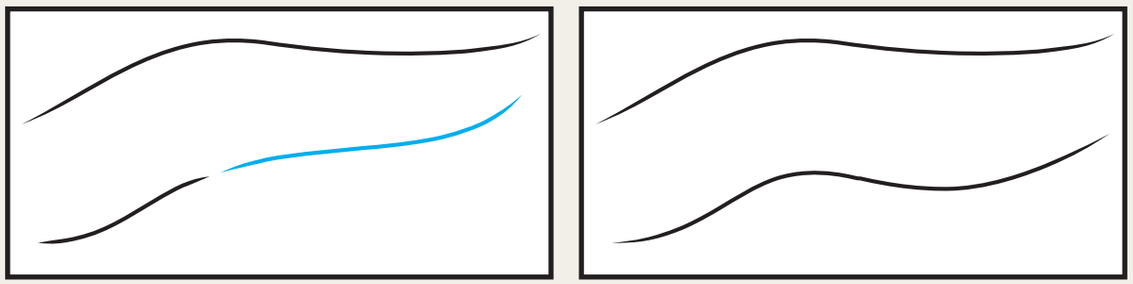
Streamline Gesture Set

New

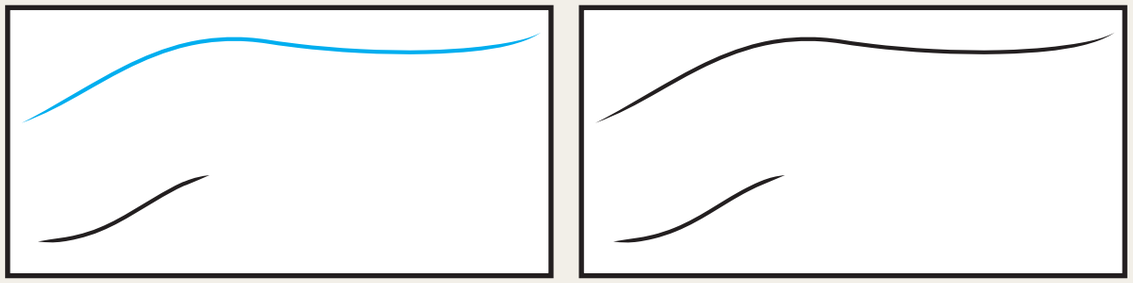


Extend

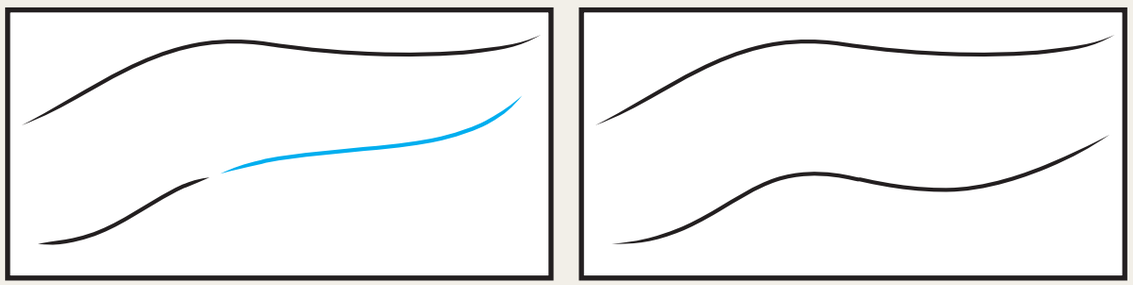


Streamline Gesture Set

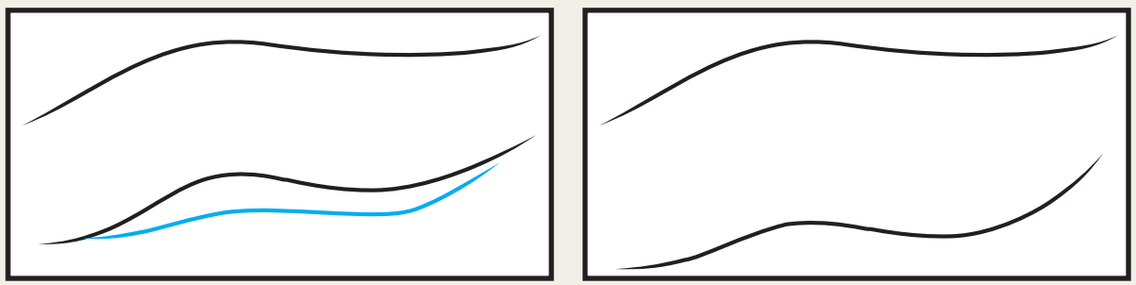
New



Extend



Refine



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Streamline Gesture Set

New

Extend

Refine

Crop

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Streamline Gesture Set

New

Extend

Refine

Crop

Delete

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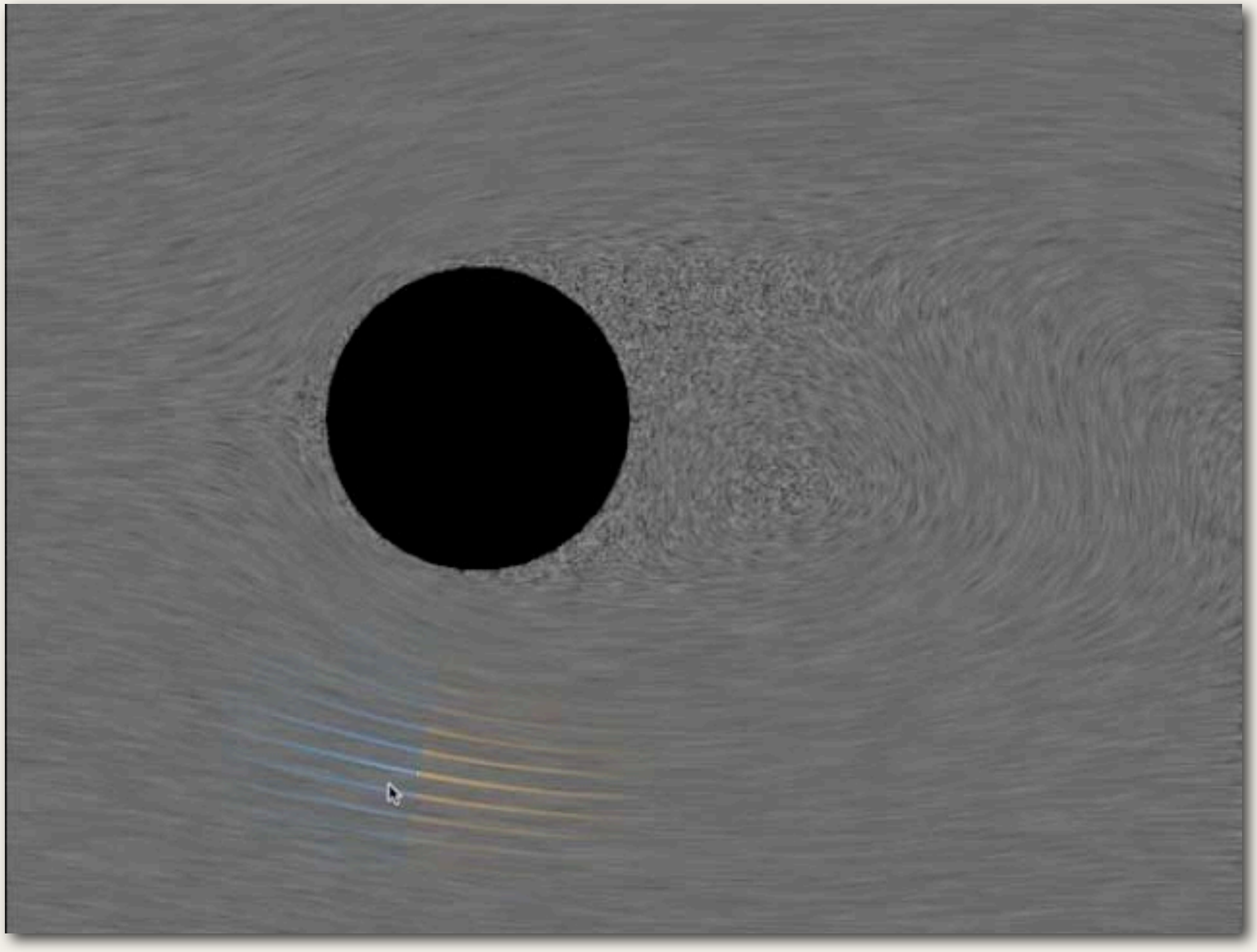
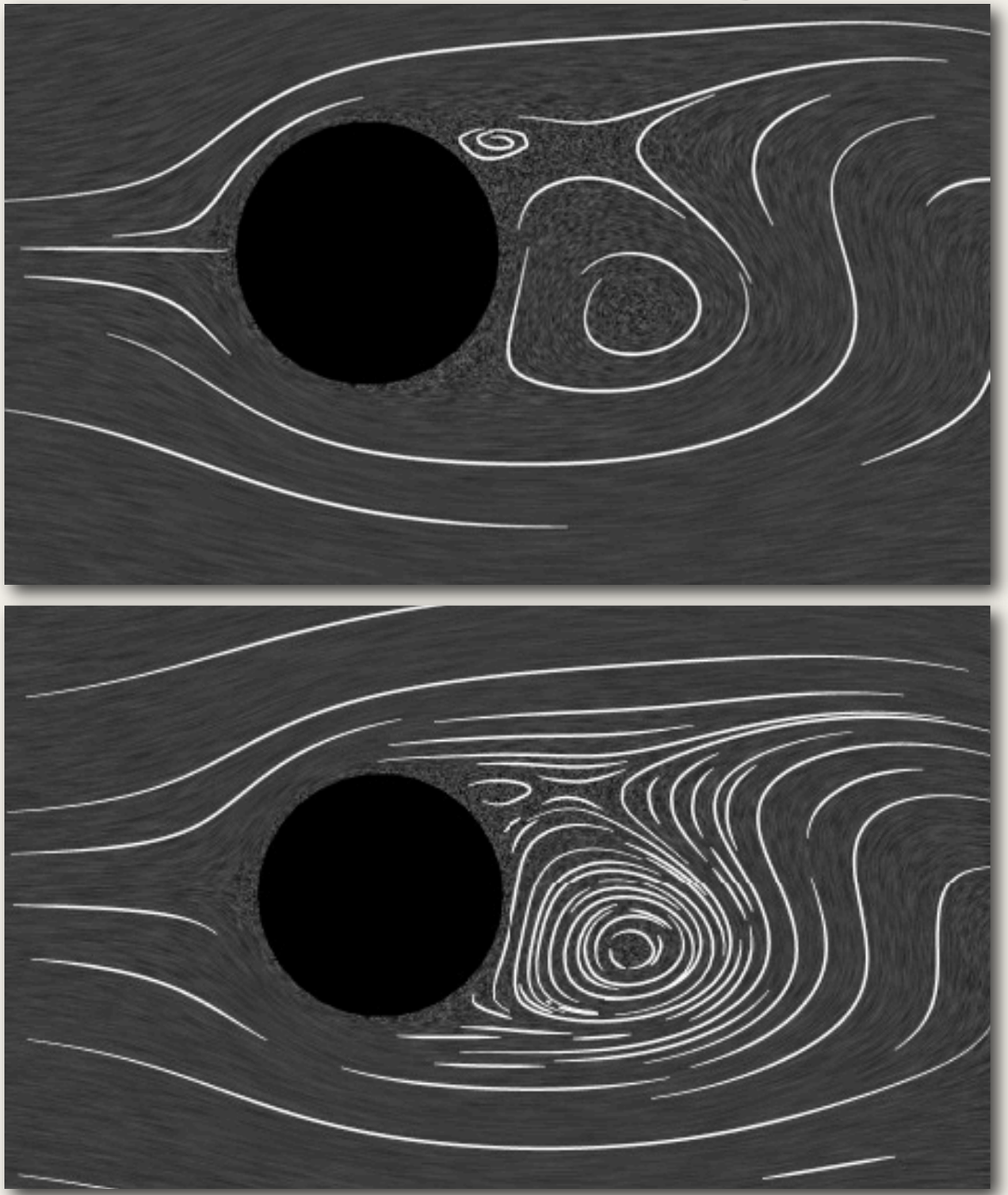
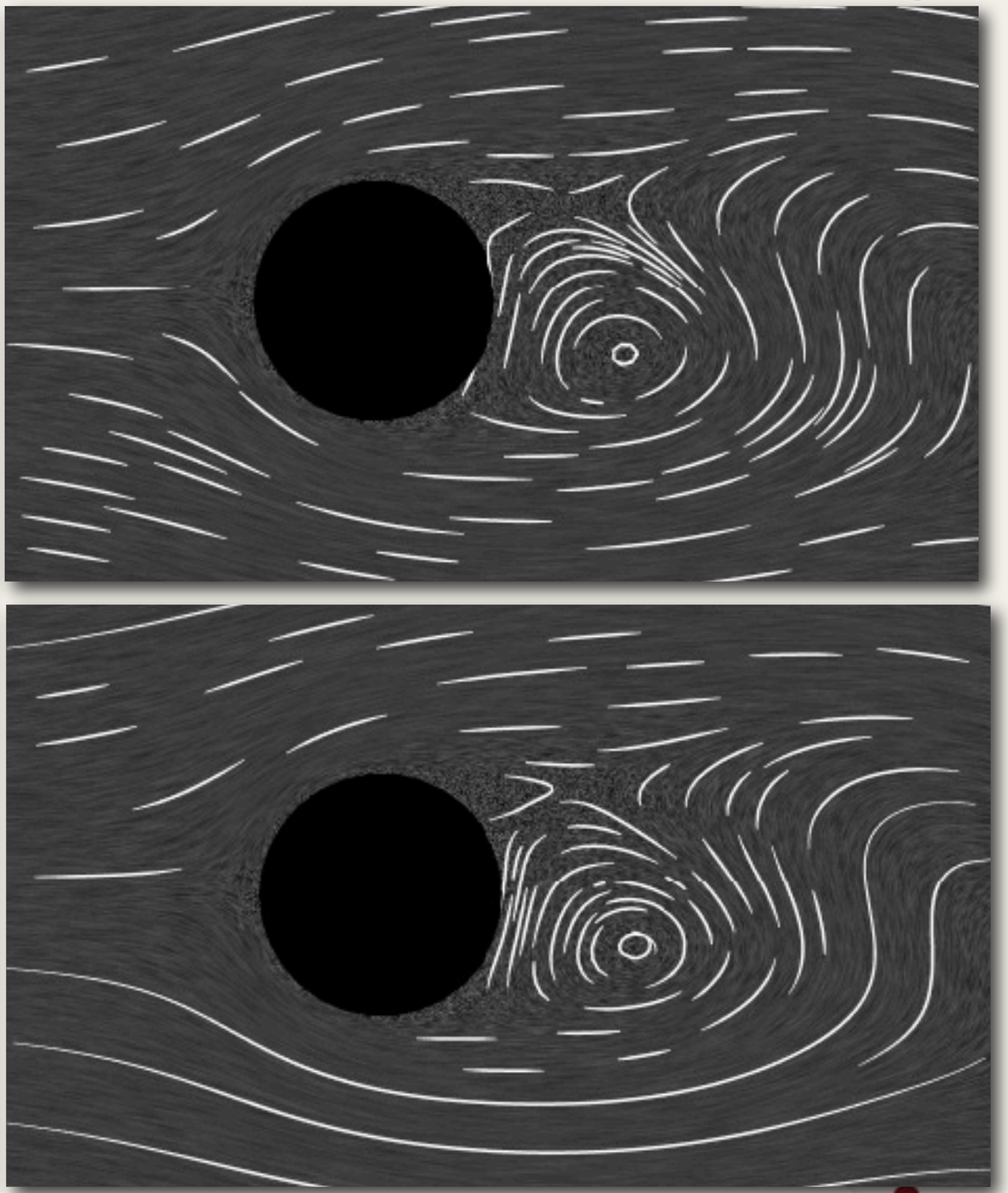
Results: Fluid Prototyping of Design Alternatives

Results: Fluid Prototyping of Design Alternatives



Possibilities through Quick Data-Driven Prototyping





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Additional Vector Fields

Virtual Prototyping Tools: Some Conclusions

- Data-intensive computing is the future -- massive datasets will come from physical and computational experiments, imaging, modeling and simulation, digitized physical artifacts, links to online data repositories, and more.
- New methods to collect, generate, and validate these data are coming; continued development here is important.
- Perhaps even more important is developing new methods to help people *do real science and engineering work* with tomorrow's massive and complex datasets.
- The key to this "real work" is enabling the human activity of moving from data to insight -- visualization and interactive analysis tools are critical for this.

Thanks to

Our students:

- Dane Coffey, Bret Jackson, Fedor Korsakov, Cyrus Lin, Cory Schaffhausen, David Schroeder, Lauren Thorson.

Additional co-authors and providers of data and driving problems:

- Fritz Drury, Mike Kirby, David Laidlaw, Jadrian Miles, Sharon Swartz, Bob Zeleznik.
- NCAR & NSF
- NLM Visible Human

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- NSF (CAREER Award IIS-1054783 and Award IIS-1218058)
- National Academies and W.M. Keck Foundation
- University of Minnesota Digital Technology Center
- University of Minnesota Office of VP for Research