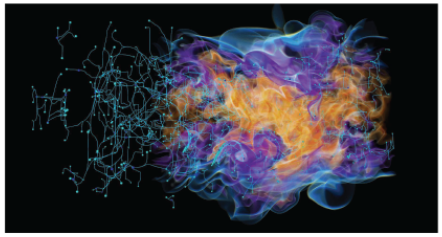
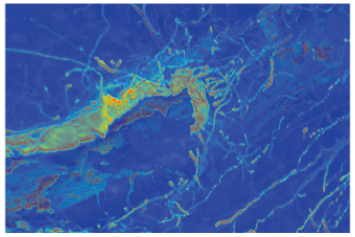
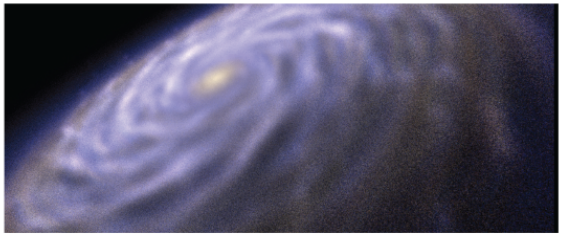
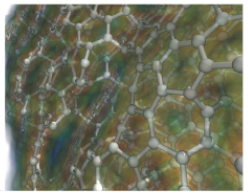
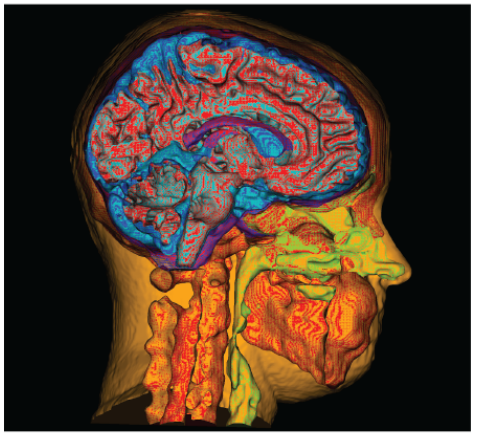
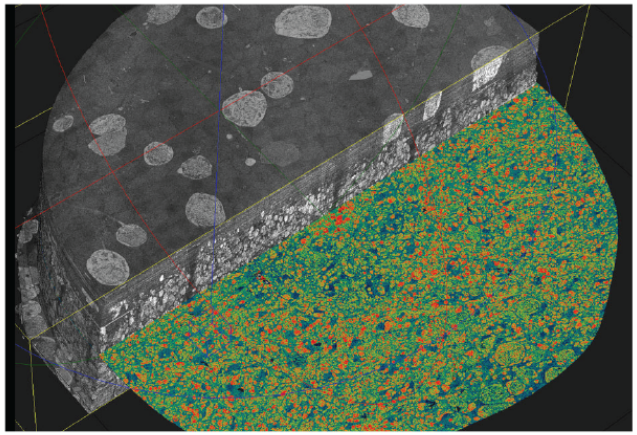
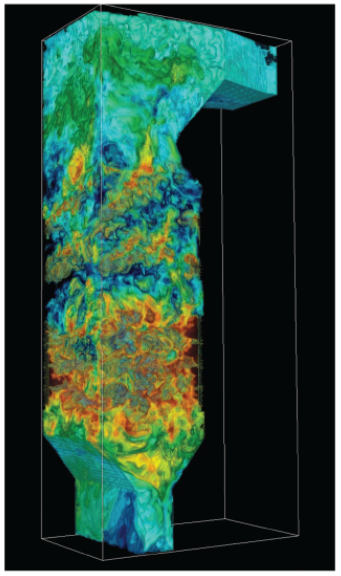
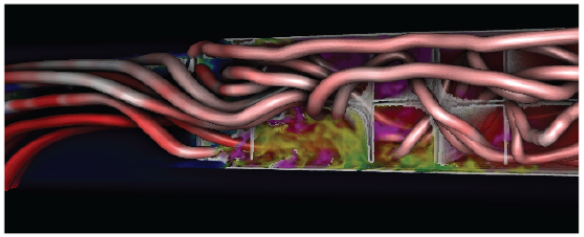
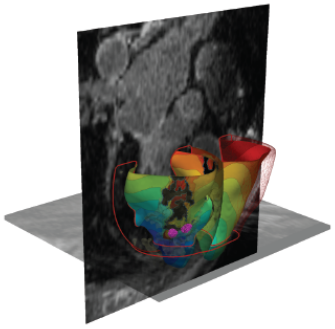
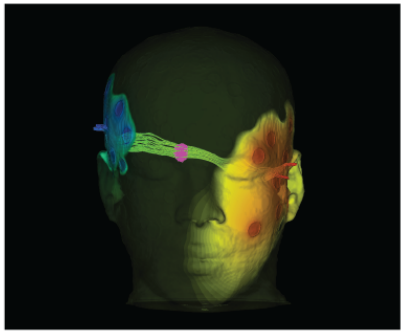
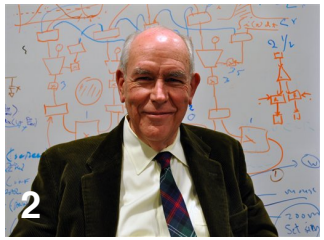
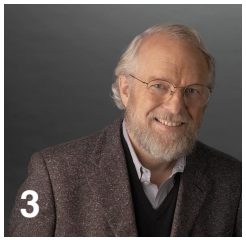
Visual Analysis in the Age of Data

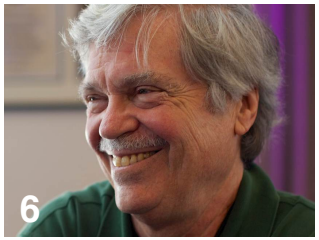










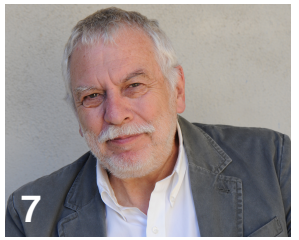


Computer Graphics at Utah









1, 2. David Evans /Ivan Sutherland
- Founded CS Dept at the UofU in 1968
- Ivan Sutherland - Turing award
- Founded Evans & Sutherland Company

- **3. John Warnock**
- Worked at Evans & Sutherland
- Founded Adobe
- Hidden Line Removal Algorithm
- Helped invent Postscript @ Adobe

4. Ed Catmull
- Worked at Lucas Film
- Co-Founded Pixar
- President of Disney Animation Studios
- Chair of CoE External Advisory Board

5. Jim Clark
- Founded SGI, Netscape, Healtheon
- Work in Geometry Pipelines

6. Alan Kay
- Personal Computer
- Turing Award Winner
- Object Oriented Languages

7. Nolan Bushnell
- Invented Pong
- Founded Atari

8. Jim Kajyia
- Rendering Equation
- VP Research at Microsoft

9. Tom Stockham
- Known for work in Signal Processing
- Helped to invent the CD Player

10. Jim Blinn
- Invented Blinn-Phong Shading Model

11. Henri Gouraud
- Invented Gouraud Shading Model

12. Bui Tuong Phong
- Invented Phong Reflection and Shading Models

13. Allen Ashton
- Word Perfect
- My CFO Founder

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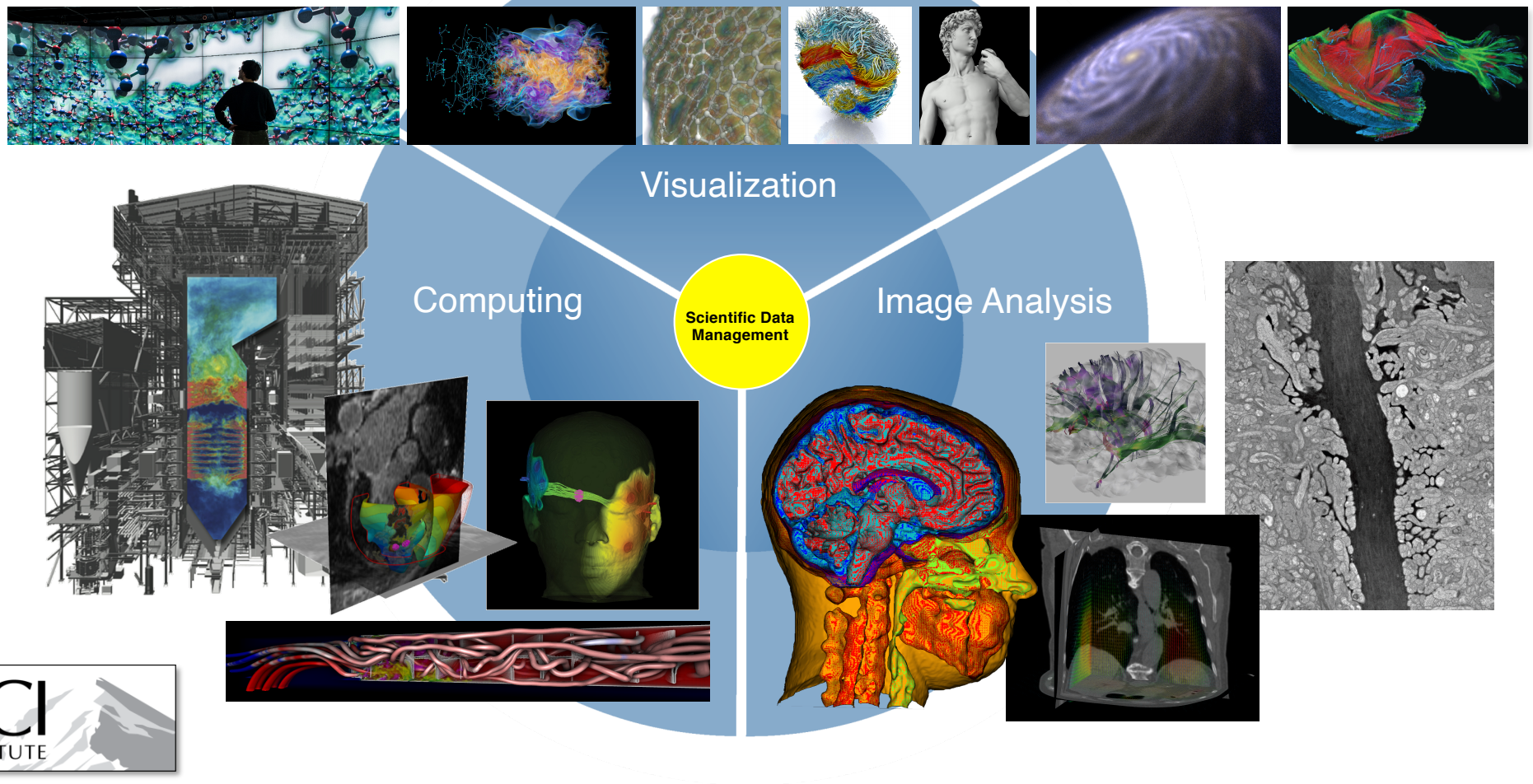
Research Cores



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Centers We Direct

NIH/NIGMS Center for Integrative Biomedical Computing

CEDMAV

UNIVERSITY OF UTAH

CENTER FOR EXTREME DATA MANAGEMENT, ANALYSIS, AND VISUALIZATION

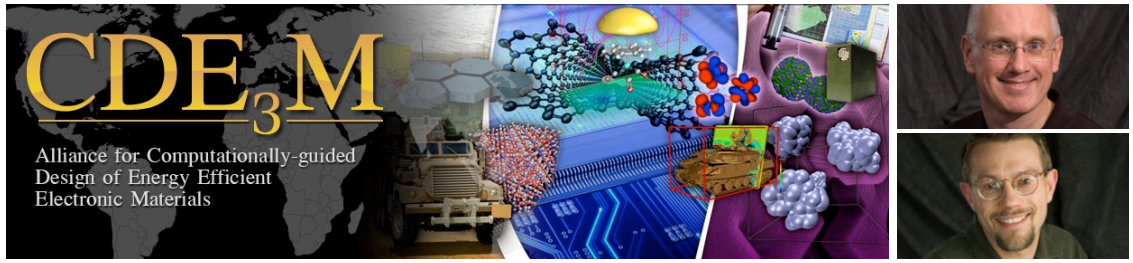
intel Graphics and Visualization Institute

Utah Center for Computational Earth Sciences

at the Scientific Computing and Imaging Institute

CDE$_3$M

Alliance for Computationally-guided Design of Energy Efficient Electronic Materials



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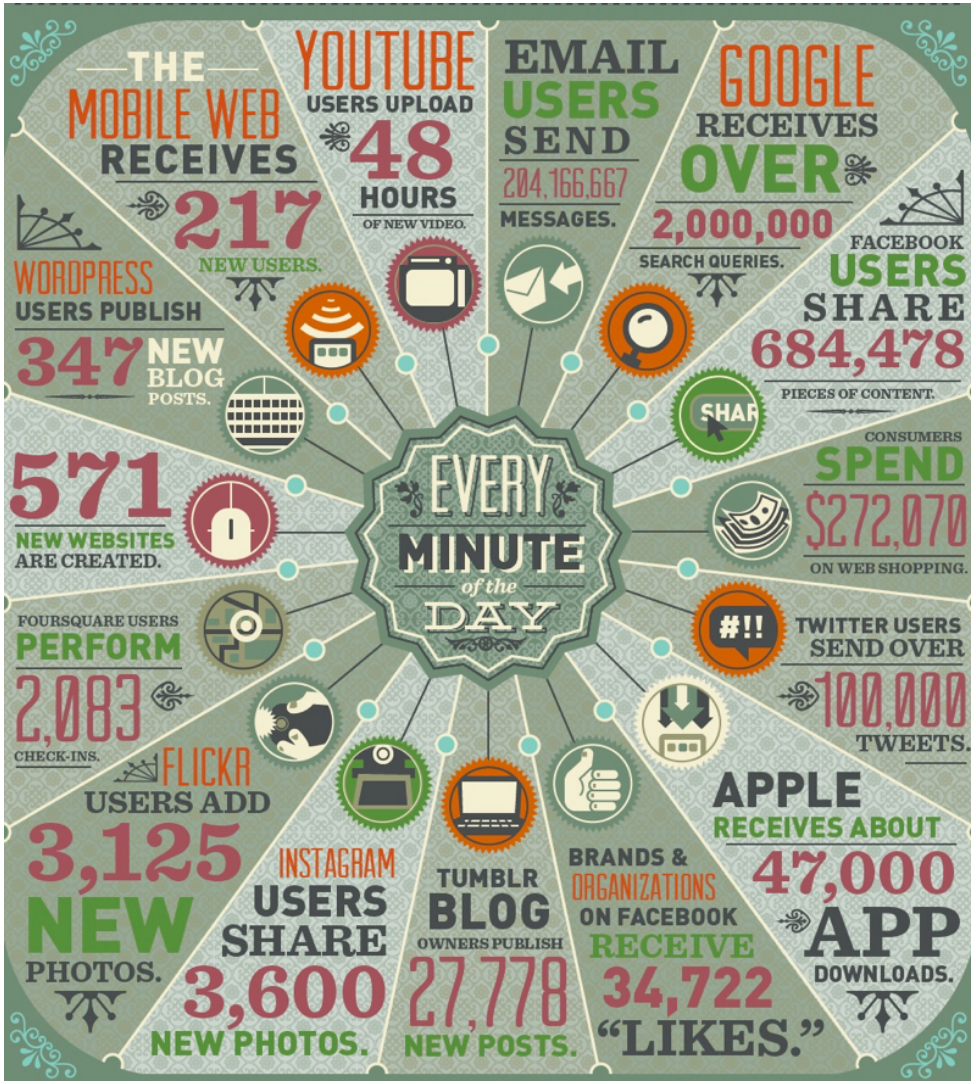
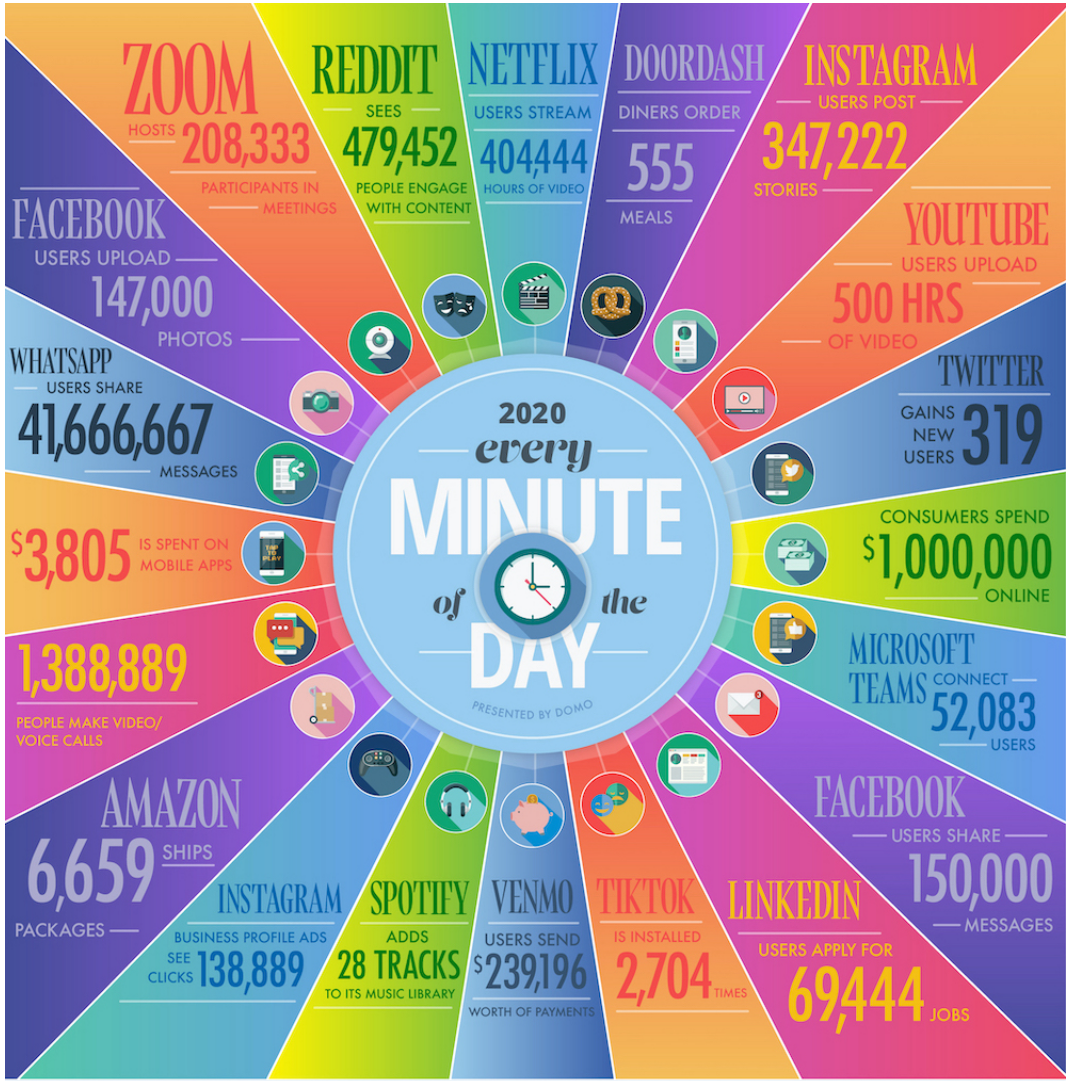
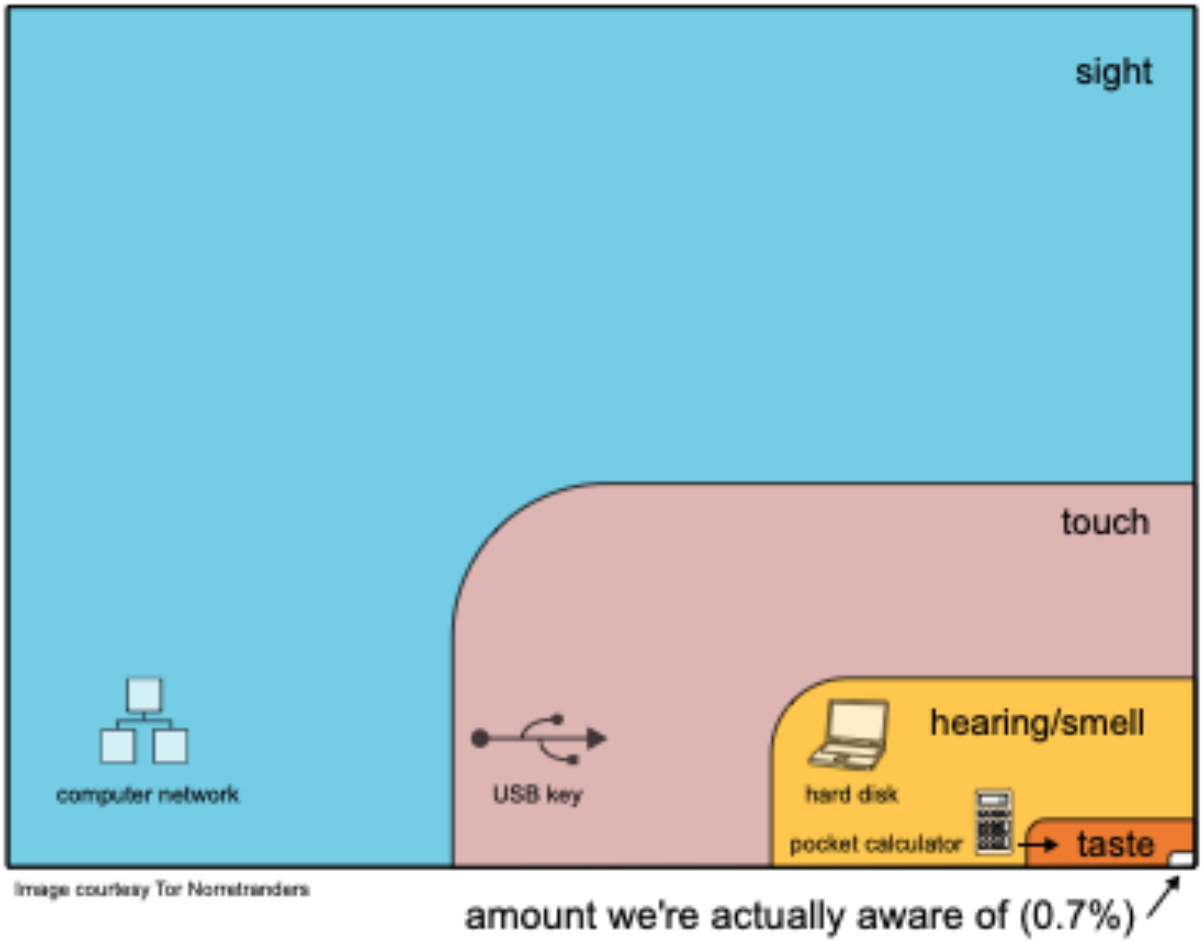

EVERY MINUTE of the DAY
THE MOBILE WEB RECEIVES 217 NEW USERS.
YOUTUBE USERS UPLOAD 48 HOURS OF NEW VIDEO.
EMAIL USERS SEND 204,166,667 MESSAGES.
GOOGLE RECEIVES OVER 2,000,000 SEARCH QUERIES.
FACEBOOK USERS SHARE 684,478 PIECES OF CONTENT.
WORDPRESS USERS PUBLISH 347 NEW BLOG POSTS.
571 NEW WEBSITES ARE CREATED.
CONSUMERS SPEND $272,070 ON WEB SHOPPING.
FOURSQUARE USERS PERFORM 2,083 CHECK-INS.
TWITTER USERS SEND OVER 100,000 TWEETS.
FLICKR USERS ADD 3,125 NEW PHOTOS.
INSTAGRAM USERS SHARE 3,600 NEW PHOTOS.
TUMBLR BLOG OWNERS PUBLISH 27,778 NEW POSTS.
BRANDS & ORGANIZATIONS ON FACEBOOK RECEIVE 34,722 "LIKES."
APPLE RECEIVES ABOUT 47,000 APP DOWNLOADS.


2020 every MINUTE of the DAY
PRESENTED BY DOMO
ZOOM HOSTS 208,333 PARTICIPANTS IN MEETINGS
REDDIT SEES 479,452 PEOPLE ENGAGE WITH CONTENT
NETFLIX USERS STREAM 404,444 HOURS OF VIDEO
DOORDASH DINERS ORDER 555 MEALS
INSTAGRAM USERS POST 347,222 STORIES
FACEBOOK USERS UPLOAD 147,000 PHOTOS
YOUTUBE USERS UPLOAD 500 HRS OF VIDEO
WHATSAPP USERS SHARE 41,666,667 MESSAGES
TWITTER GAINS NEW USERS 319
$3,805 IS SPENT ON MOBILE APPS
CONSUMERS SPEND $1,000,000 ONLINE
1,388,889 PEOPLE MAKE VIDEO/ VOICE CALLS
MICROSOFT TEAMS CONNECT 52,083 USERS
AMAZON 6,659 SHIPS PACKAGES
FACEBOOK USERS SHARE 150,000 MESSAGES
INSTAGRAM BUSINESS PROFILE ADS SEE CLICKS 138,889
SPOTIFY ADDS 28 TRACKS TO ITS MUSIC LIBRARY
VENMO USERS SEND $239,196 WORTH OF PAYMENTS
TIKTOK IS INSTALLED 2,704 TIMES
LINKEDIN USERS APPLY FOR 69,444 JOBS

Brain Information Bandwidth



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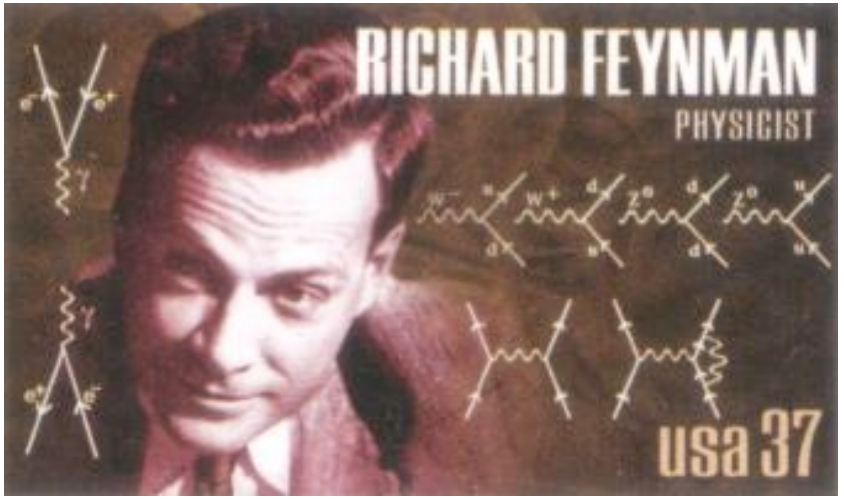
Feynman Diagrams



- Feynman: “What I am really try to do is bring birth to clarity, which is really a half-assedly thought-out-pictorial semi-vision thing. I would see the jiggle-jiggle-jiggle or the wiggle of the path. Even now when I talk about the influence functional, I see the coupling and I take this turn - like as if there was a big bag of stuff - and try to collect it in away and to push it. It's all visual. It's hard to explain.”
- James Gleick, The Life and Science of Richard Feynman, Vintage Books, New York, 1992.

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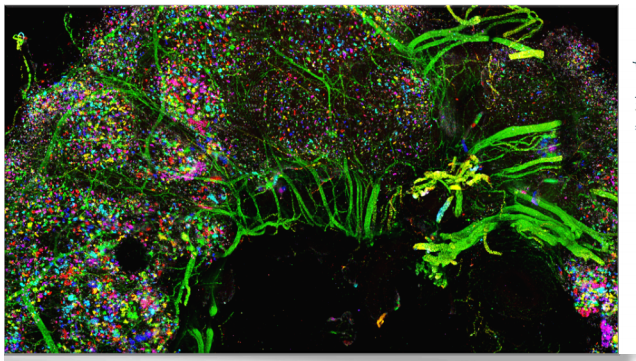
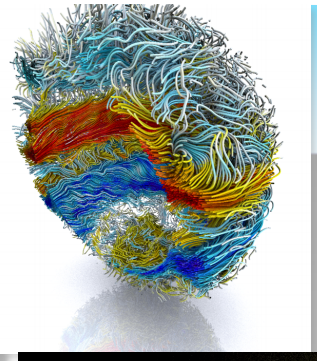
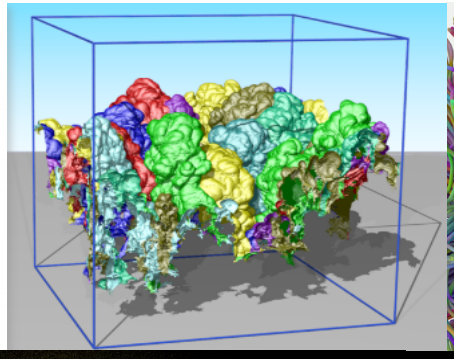

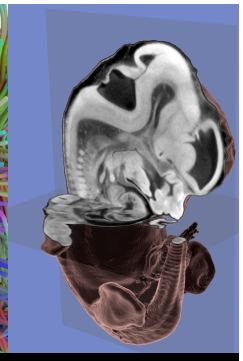

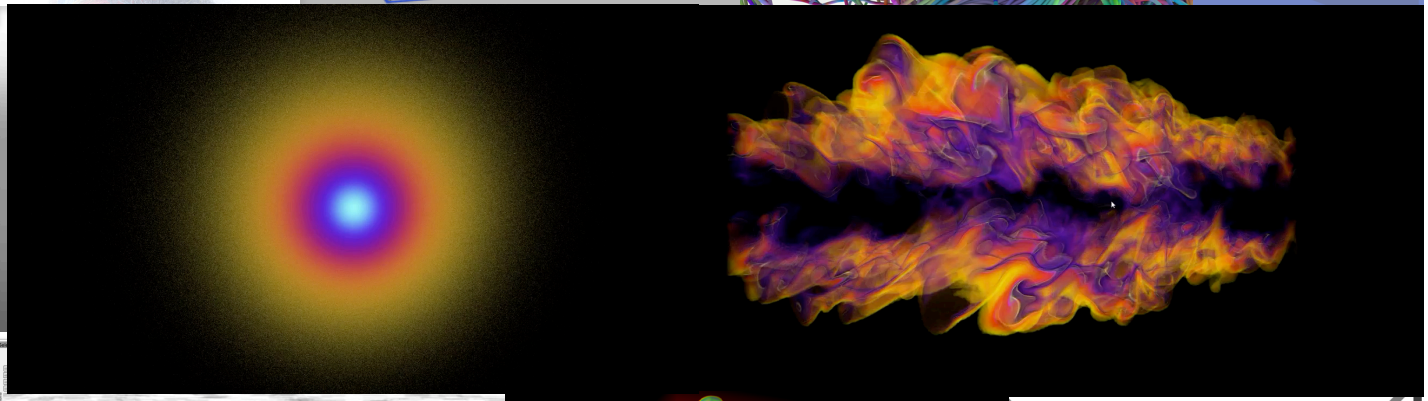
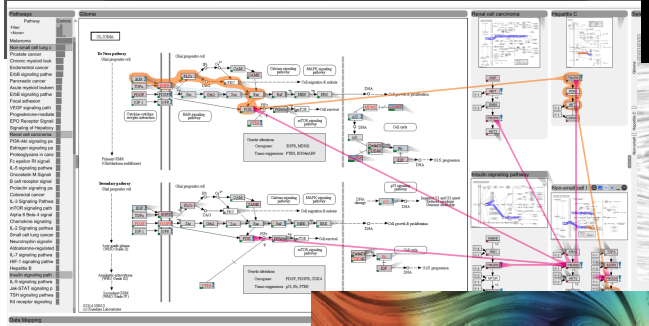
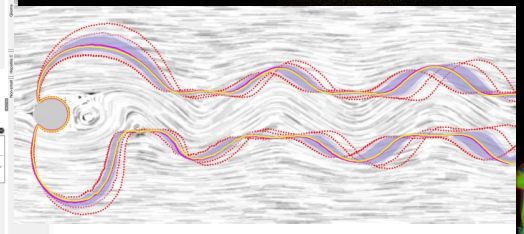
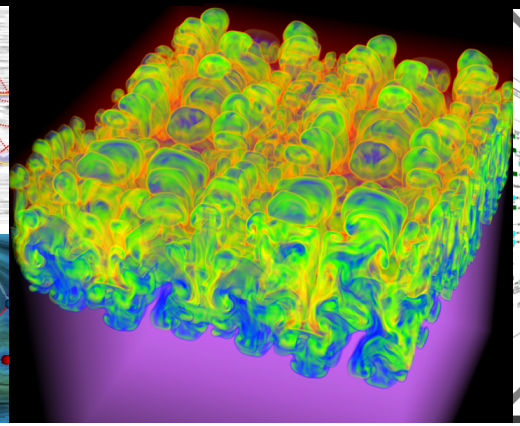
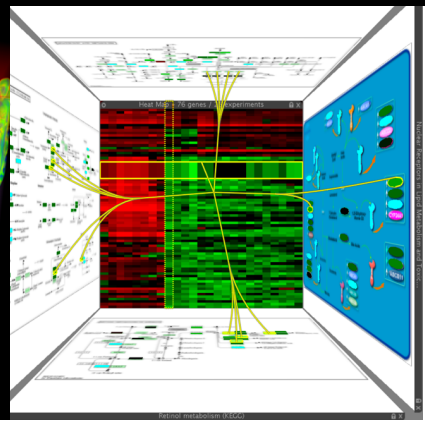
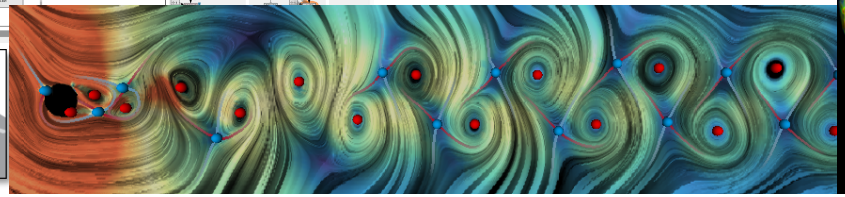


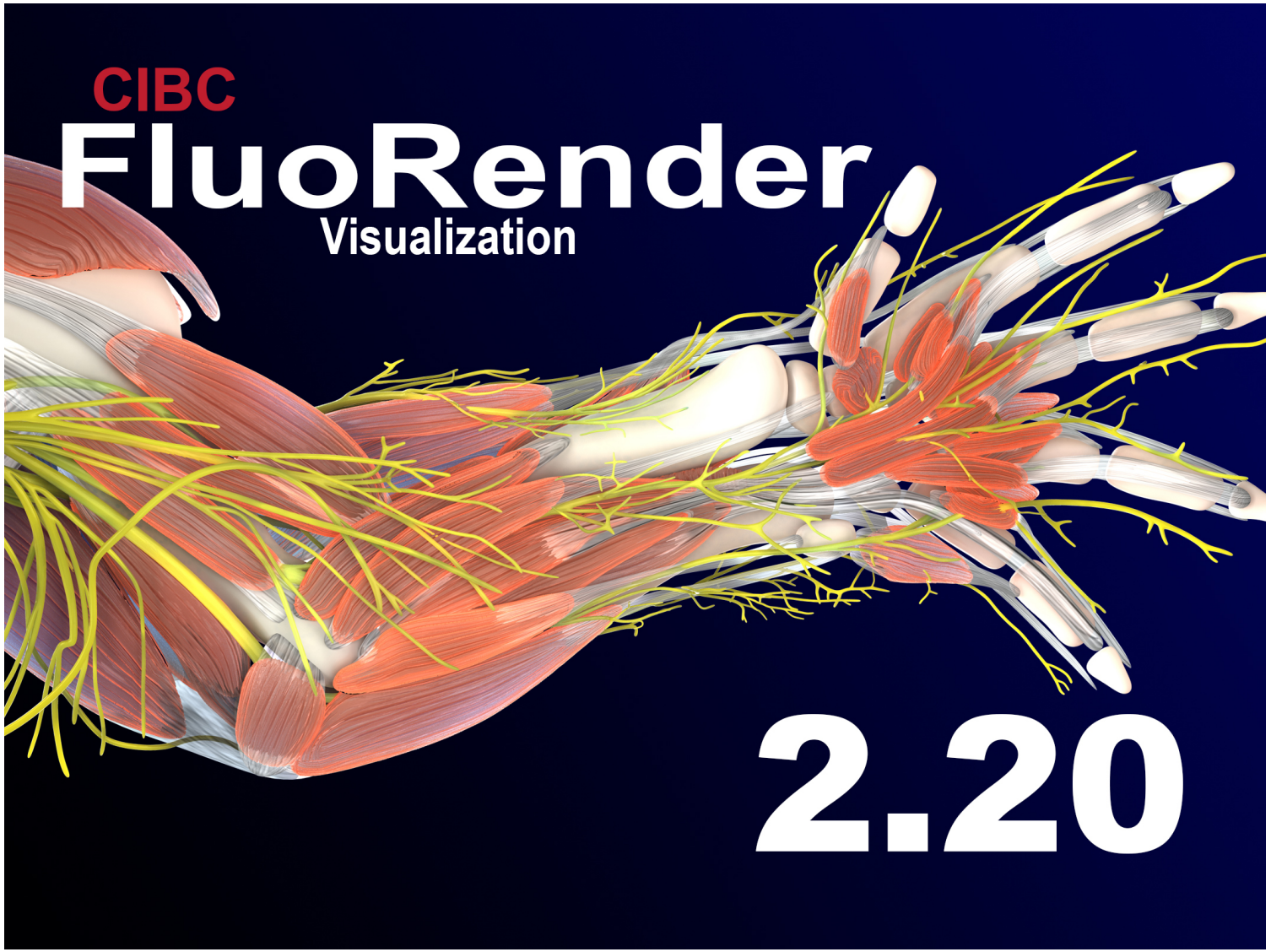

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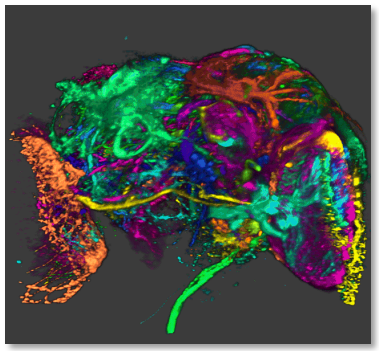
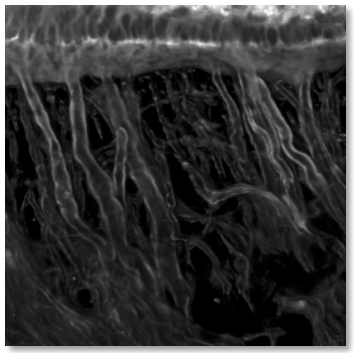
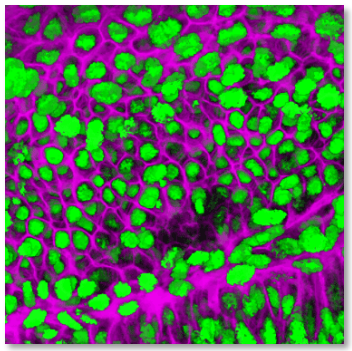
FluoRender Capabilities



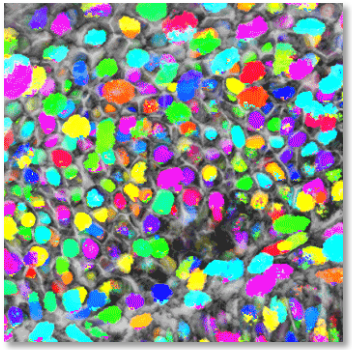
Multichannel visualization



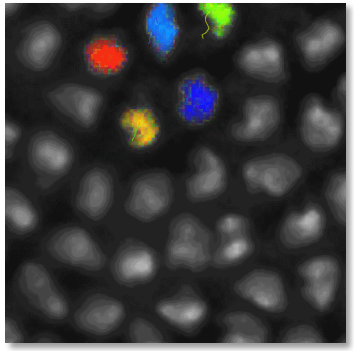
Interactive segmentation



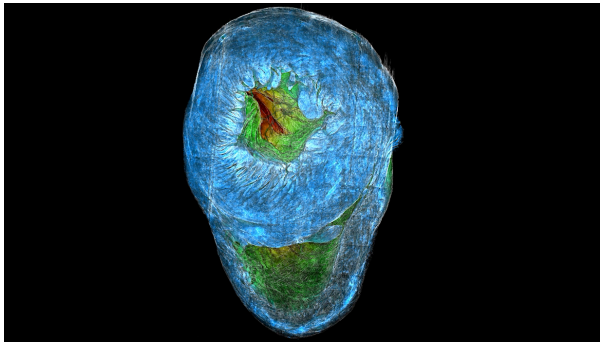
4D scan visualization



Auto segmentation on GPU



Tracking



Large-Scale Data

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FluoRender

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Michelangelo's David

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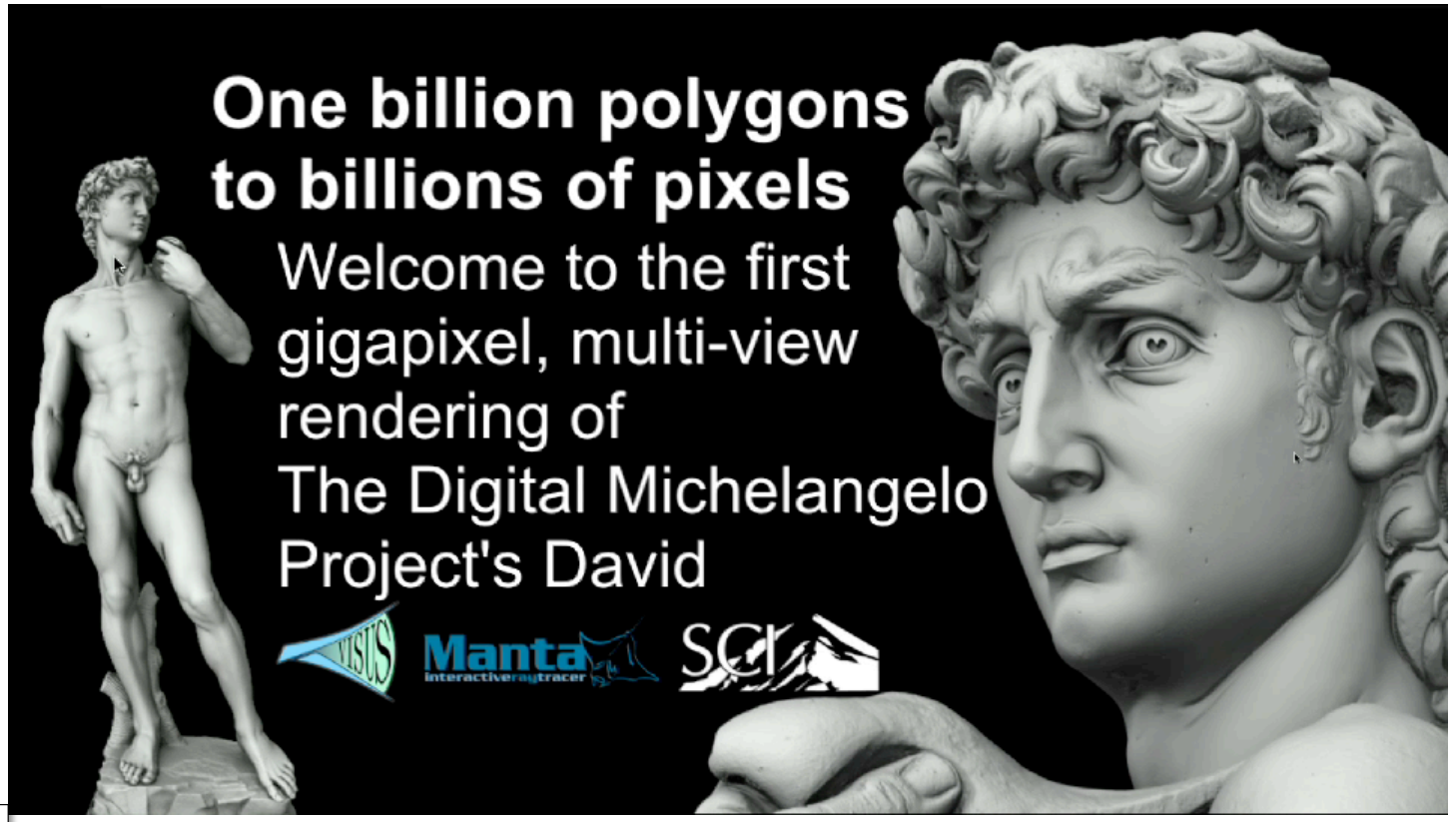
Michelangelo's David - Part 2



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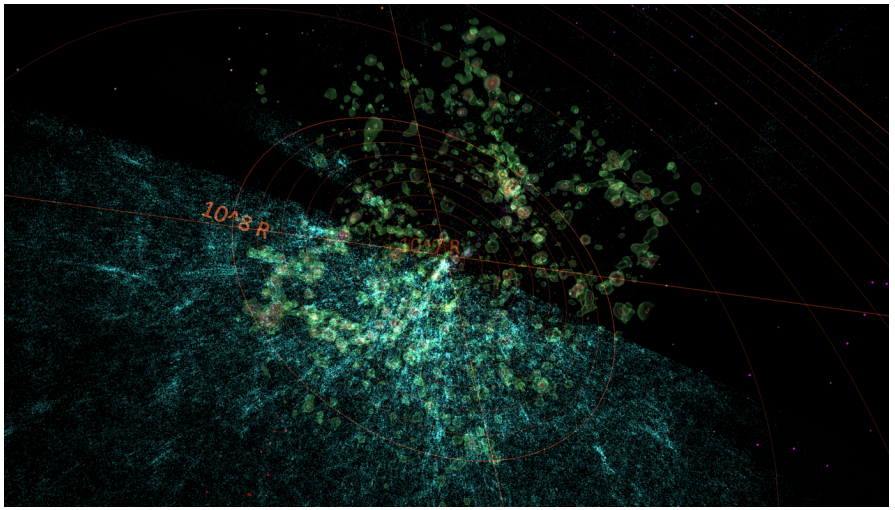
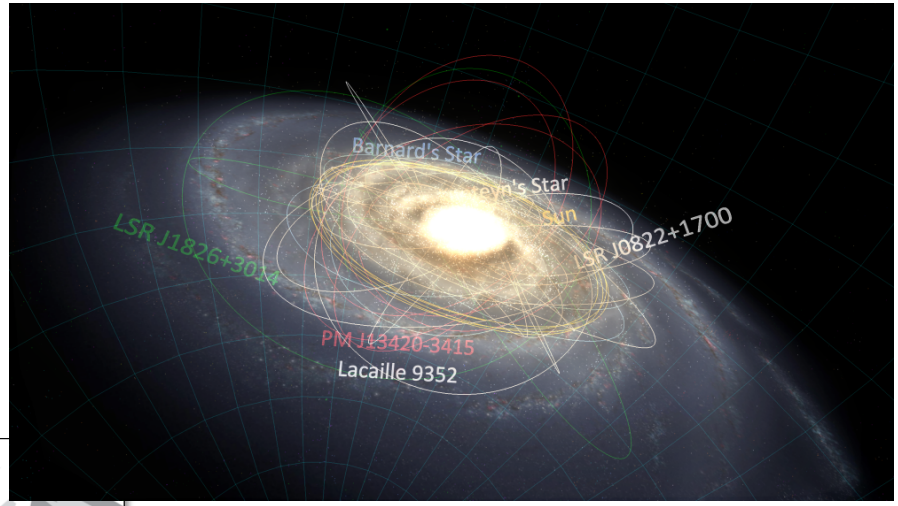
OpenSpace

Platform for:

- **Visualization Research**
- **Space & Astro Research**
- **Science Communication**





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OpenSpace Team

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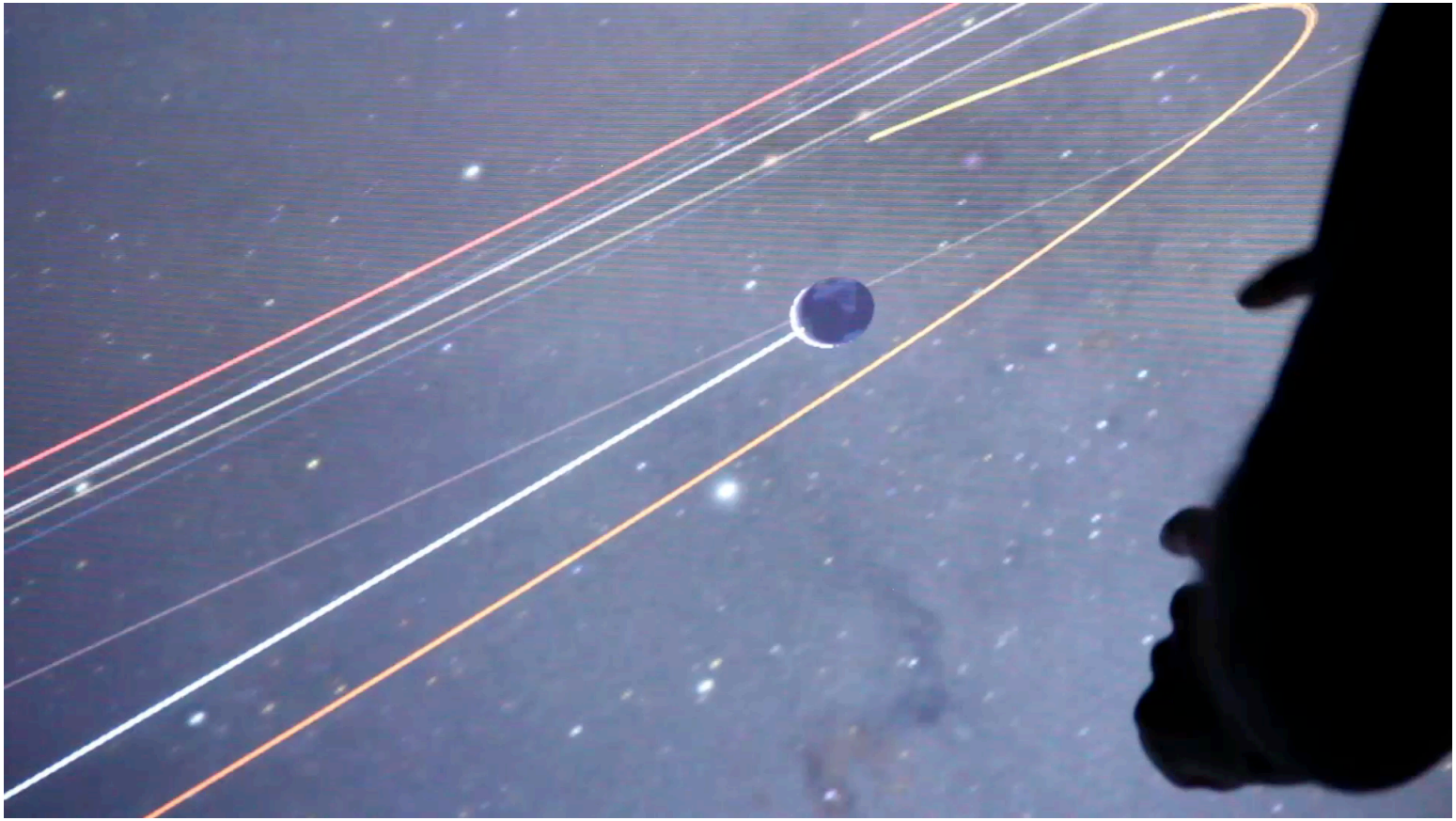
http://openspaceproject.com



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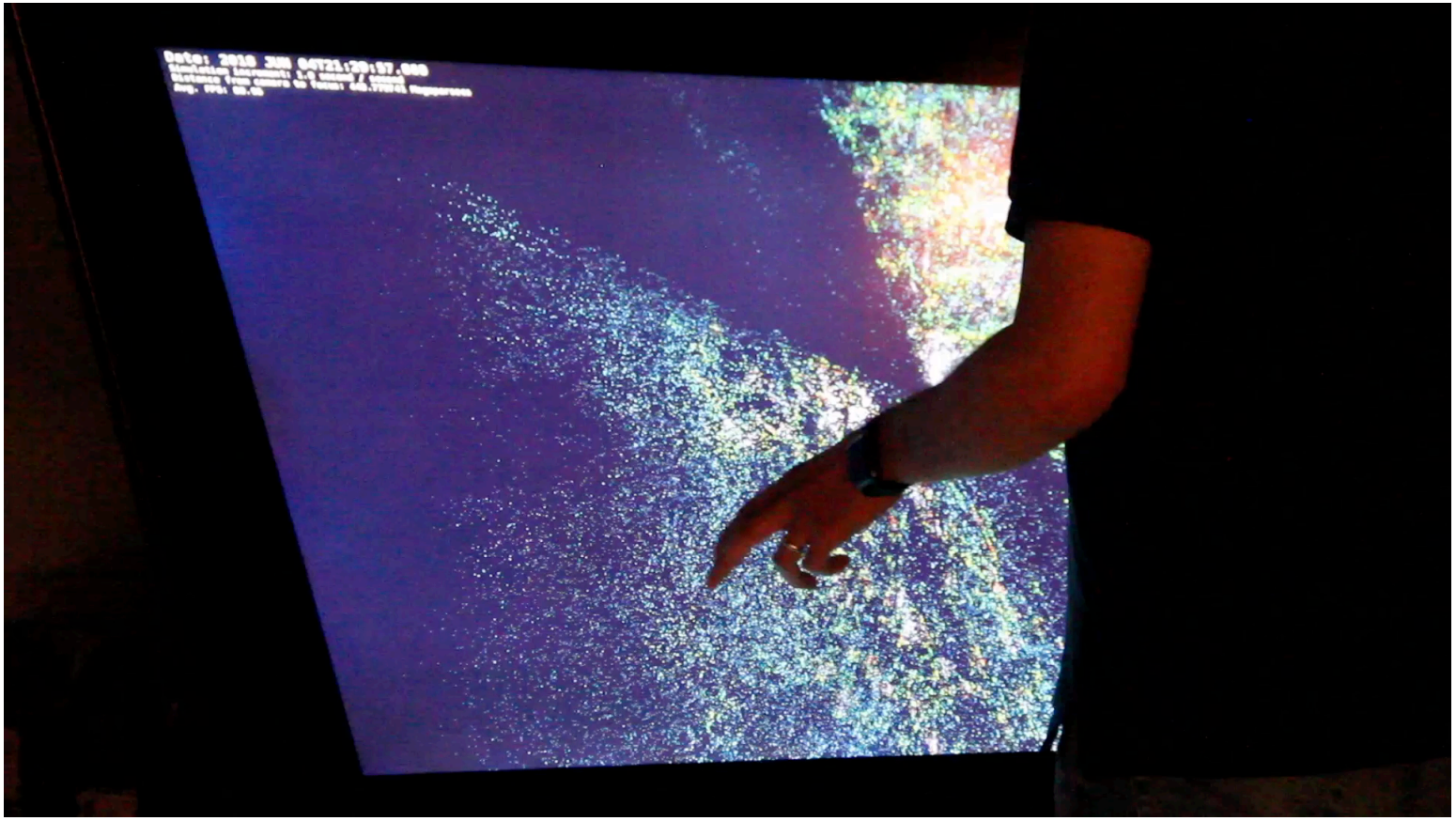

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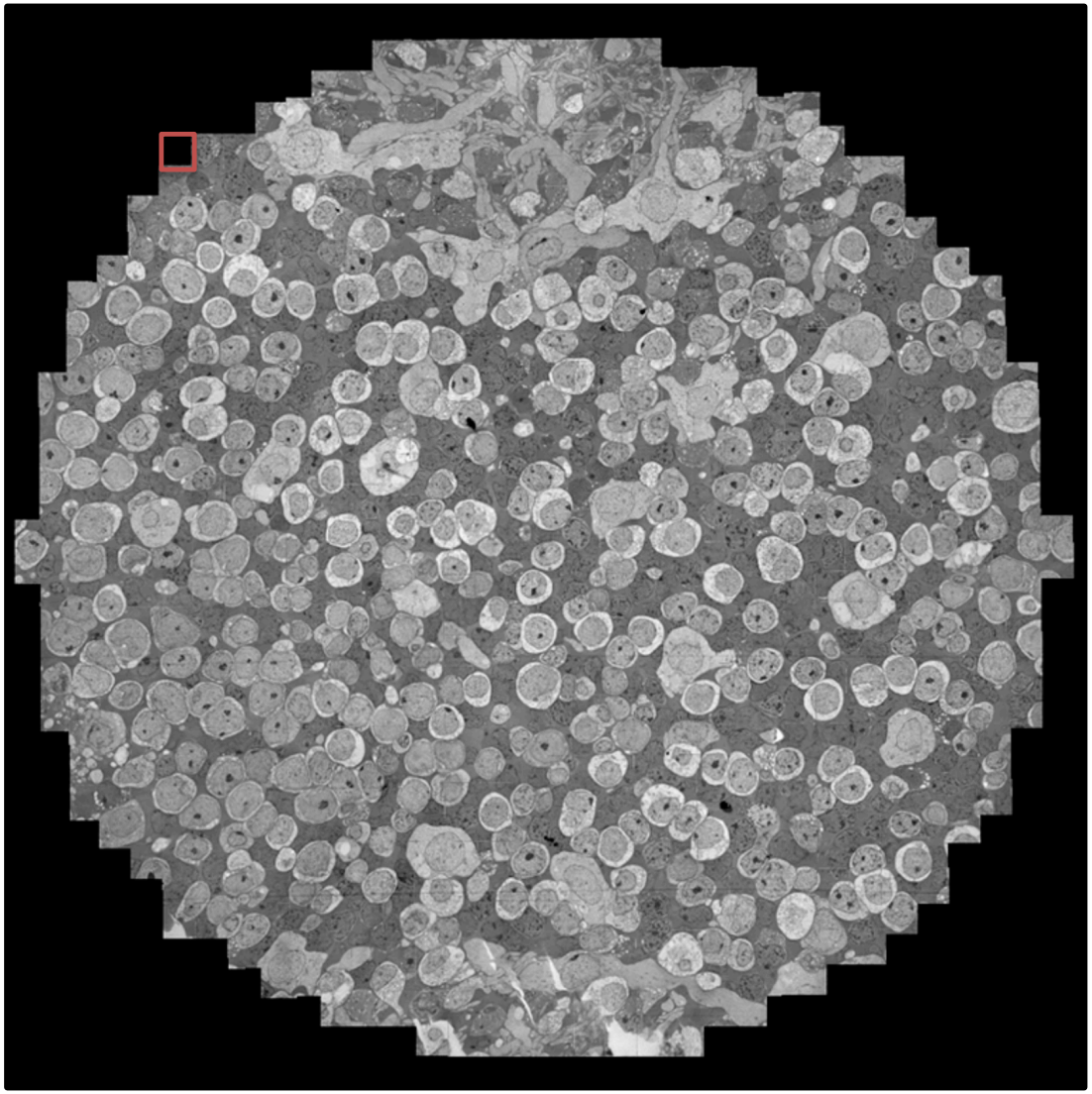

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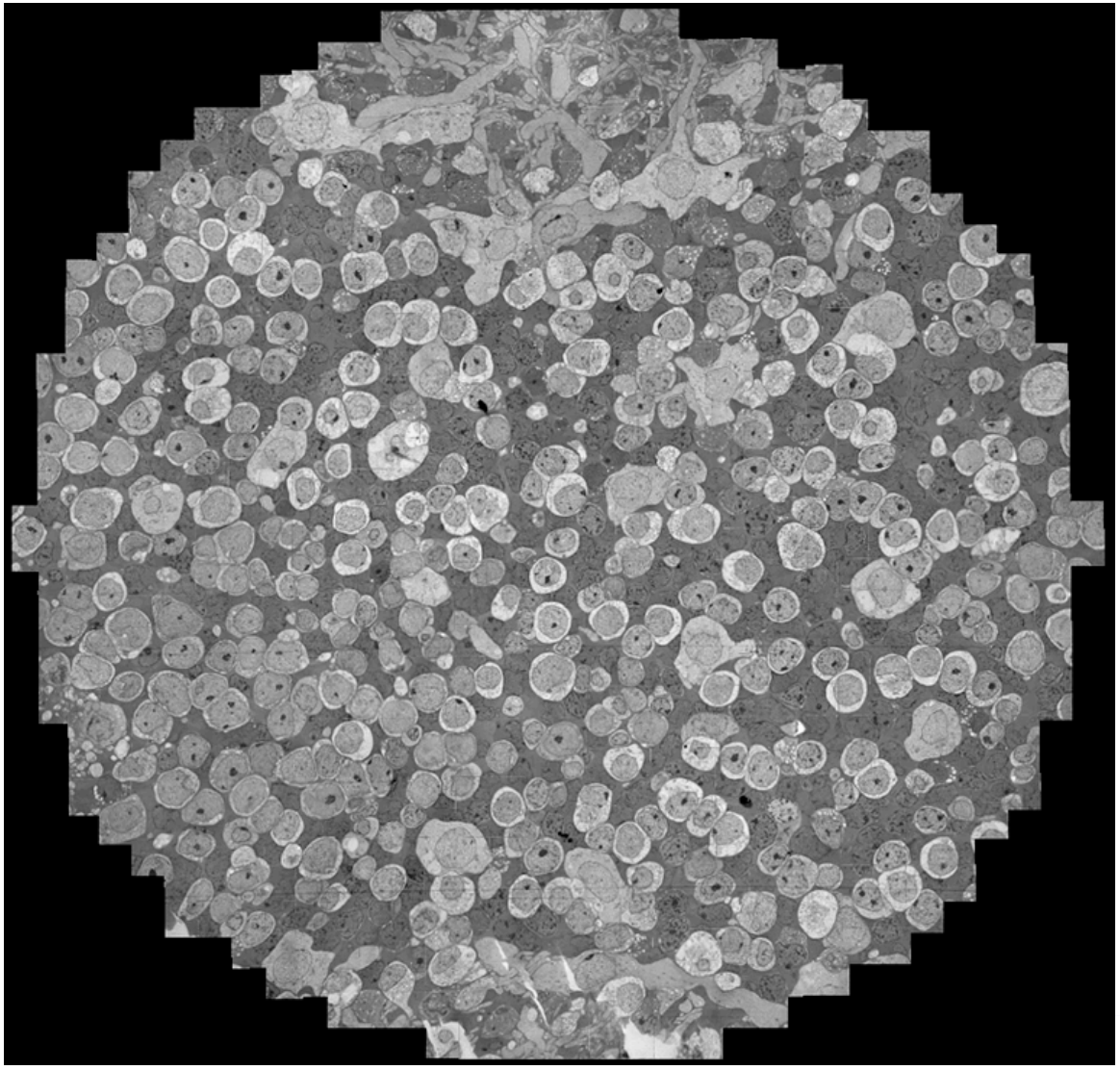

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341 Sections
90nm thick sections
~32GB/Section
~1000 tiles/section
4096x4096 pixels/tile
2.18 nm/Pixel
16.5 TB after processing

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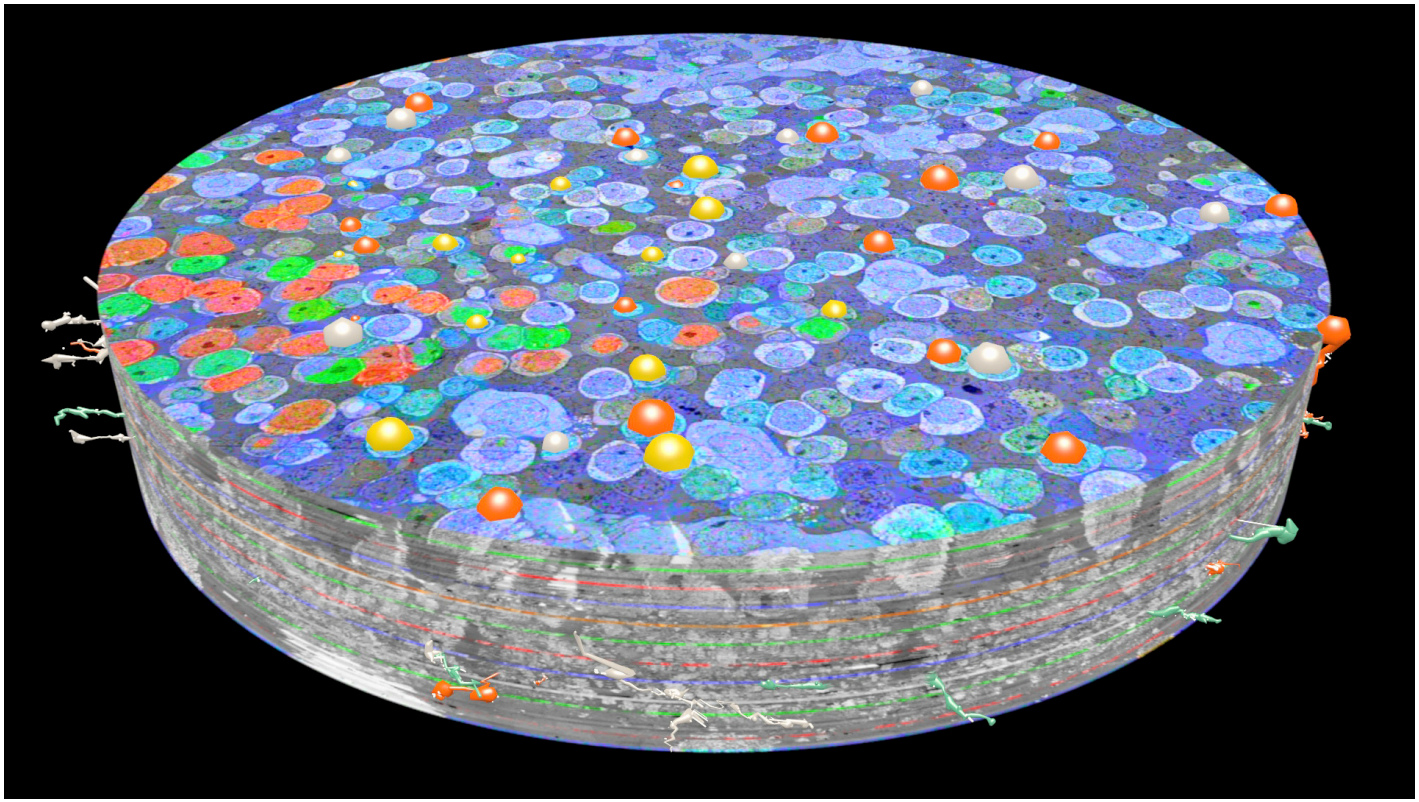
Connectome



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PROBLEM-DRIVEN VISUALIZATION RESEARCH *for biological data*

- *target specific biological problems*
- *close collaboration with biologists*
- *rapid, iterative prototyping*
- *focus on genomic and molecular data*

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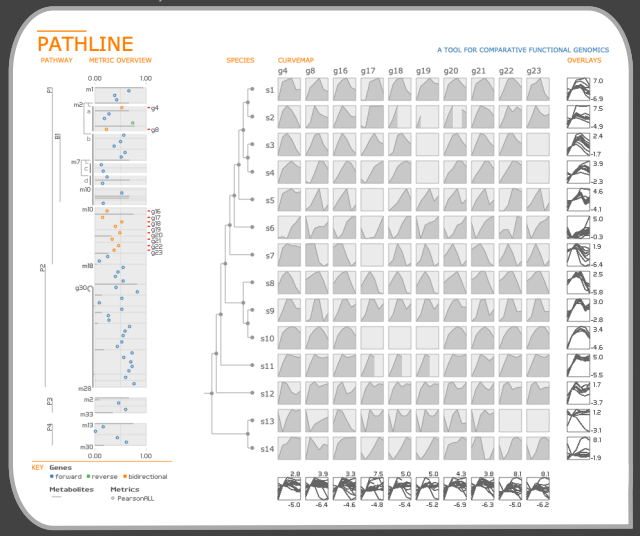
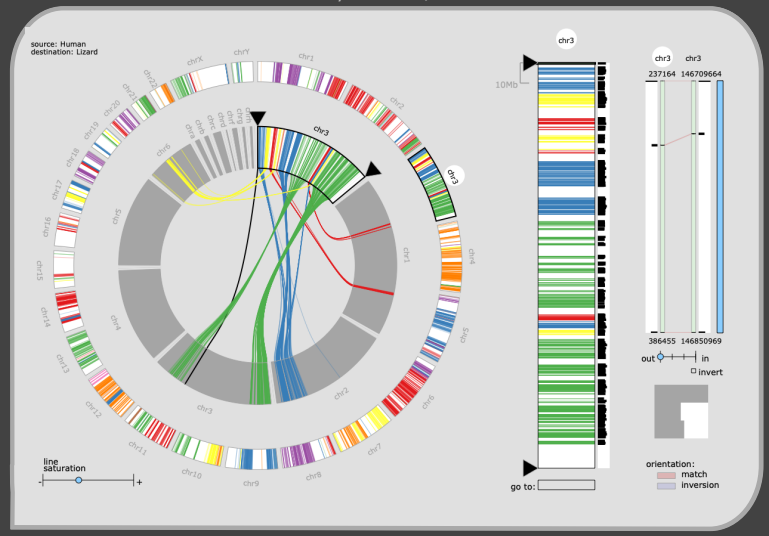
M. Meyer et al., EuroVis 2010.

Pathline



MizBee

M. Meyer et al., InfoVis 2009.



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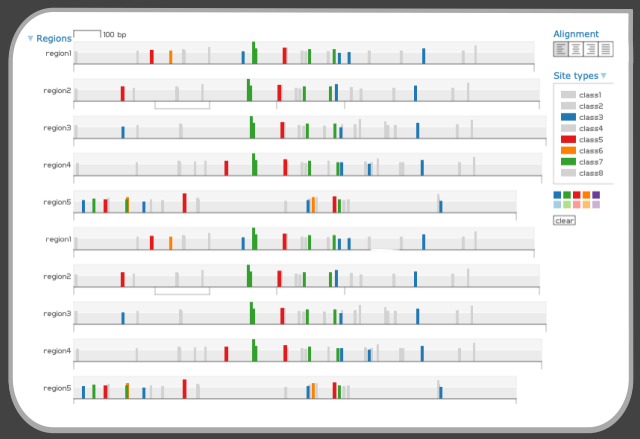
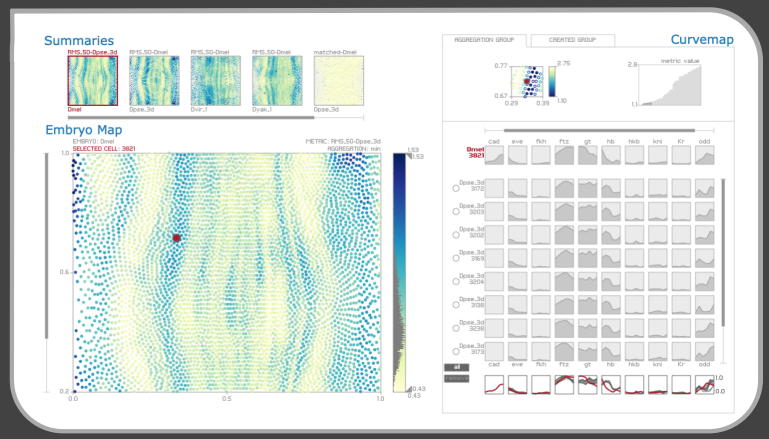


MulteeSum

M. Meyer et al., InfoVis 2010.



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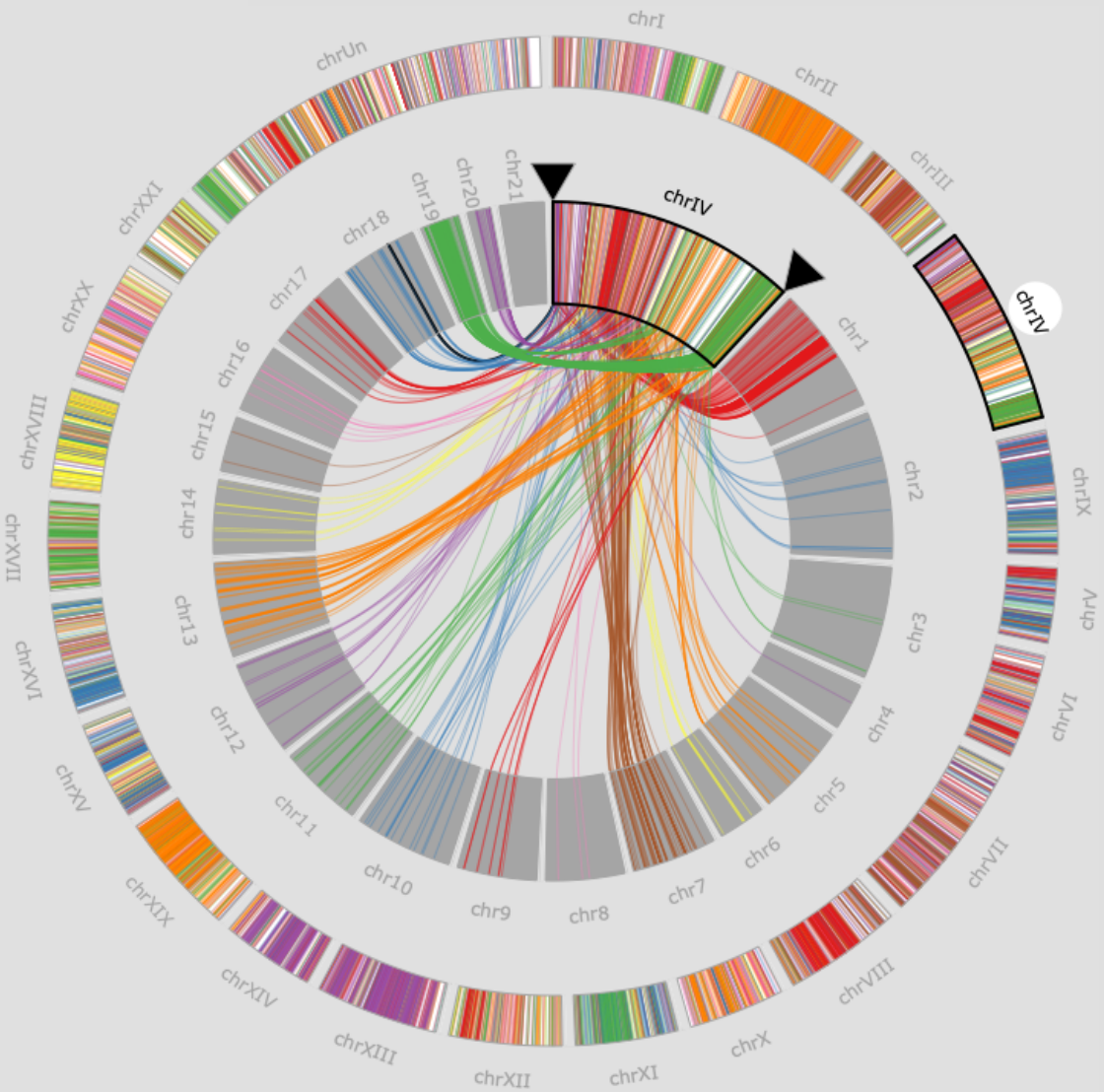

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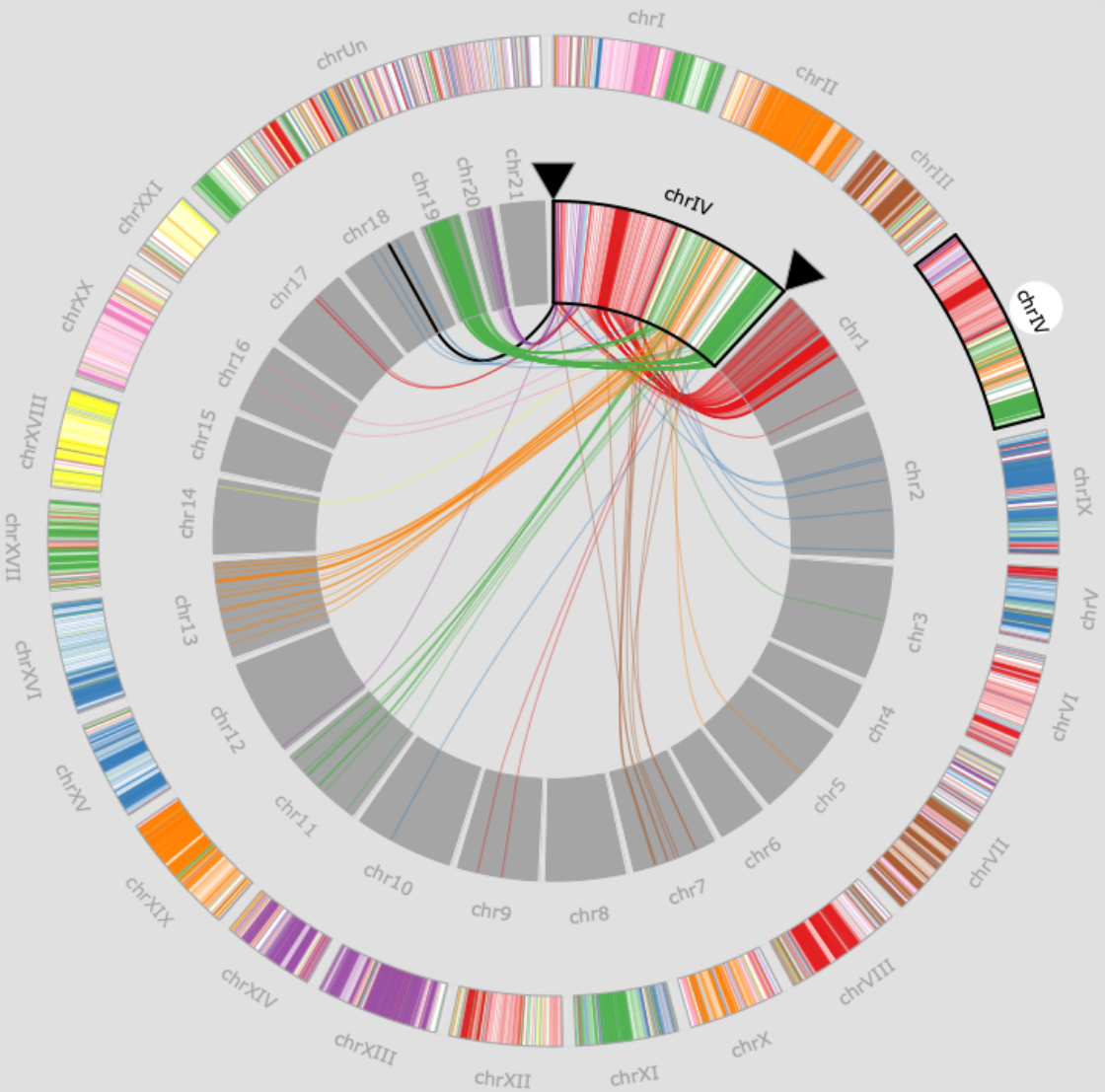

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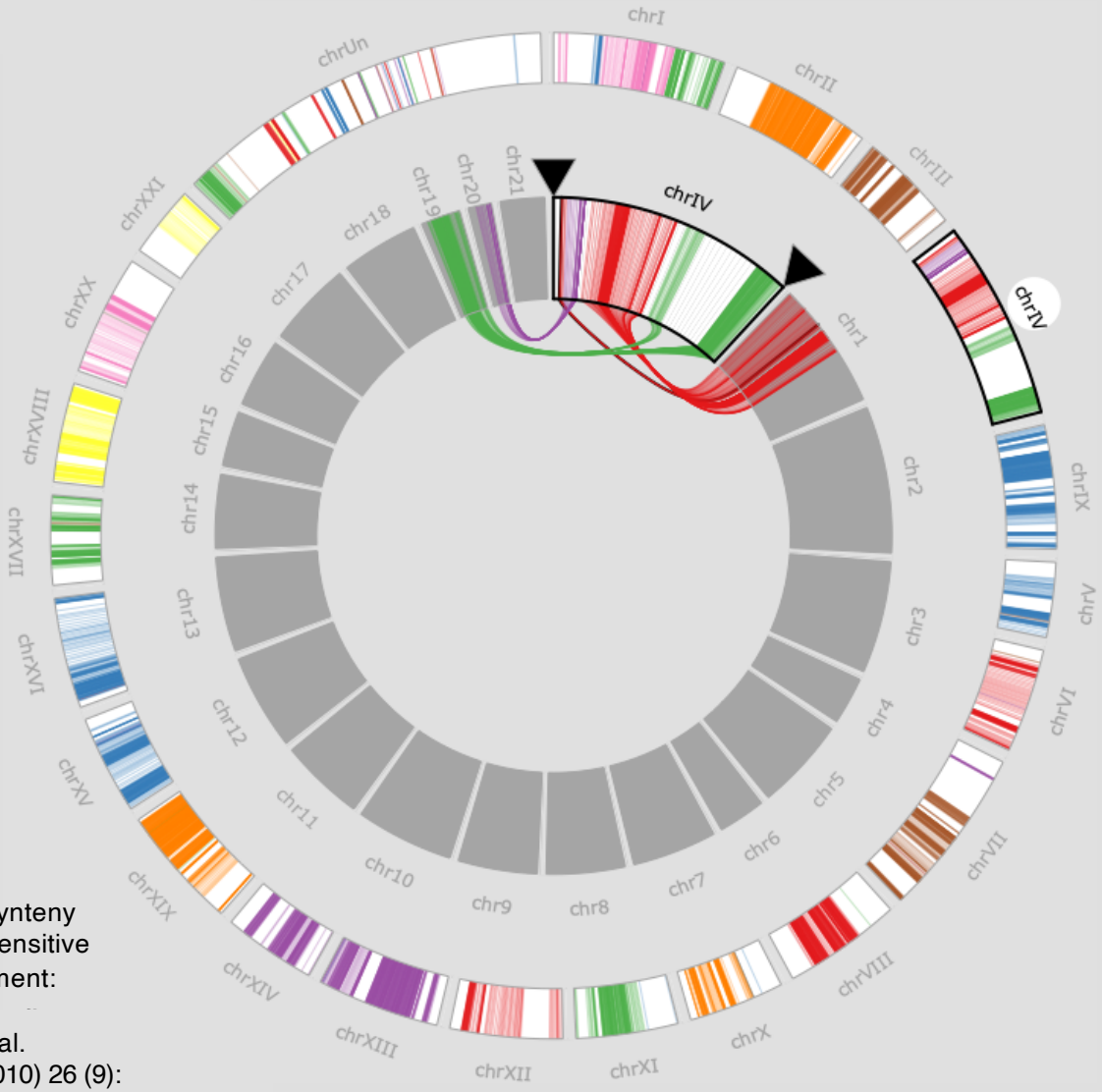
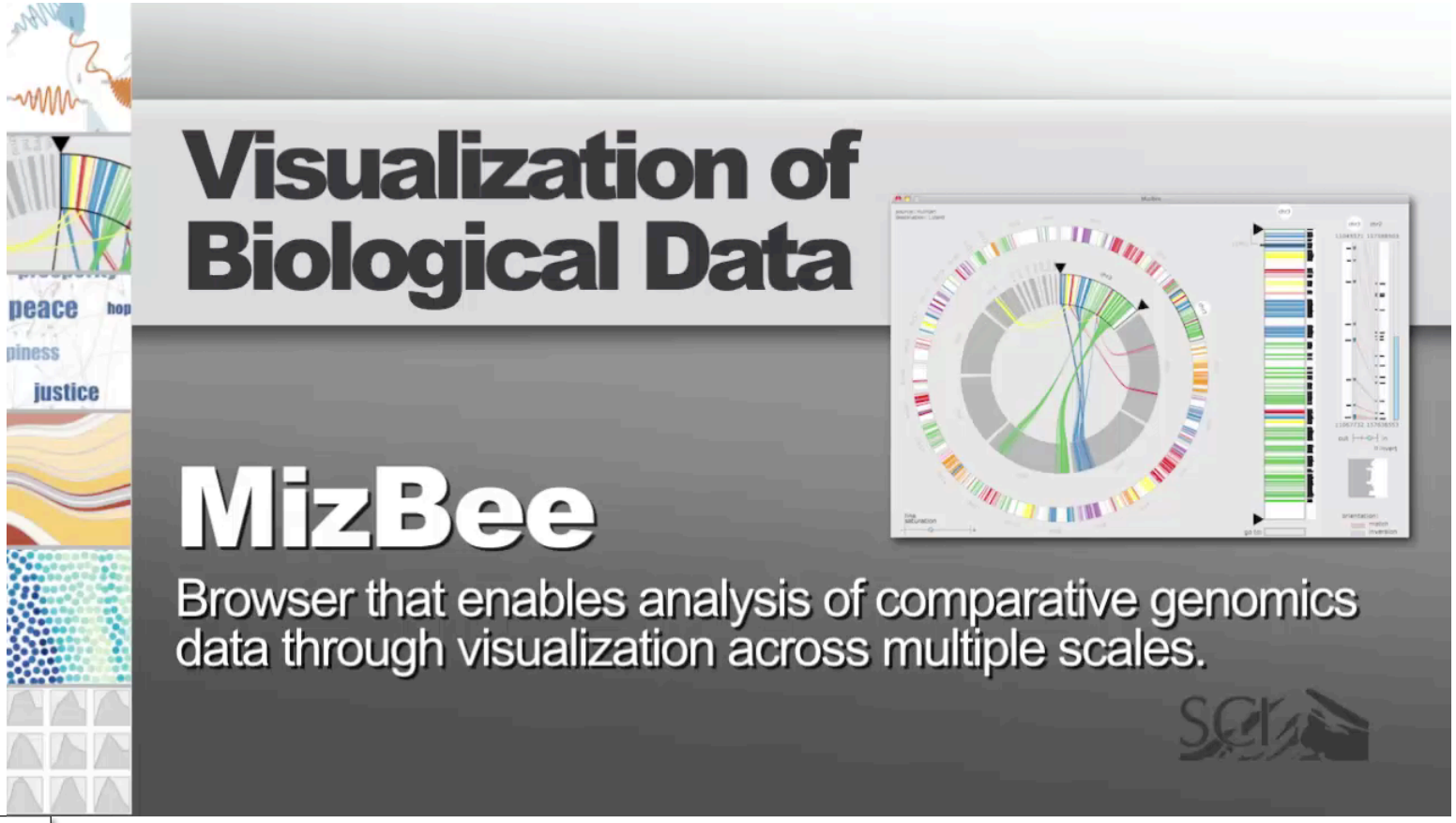


Genome-wide synteny through highly sensitive sequence alignment: Satsuma

M. Grabherr, et al.

Bioinformatics (2010) 26 (9): 1145-1151.



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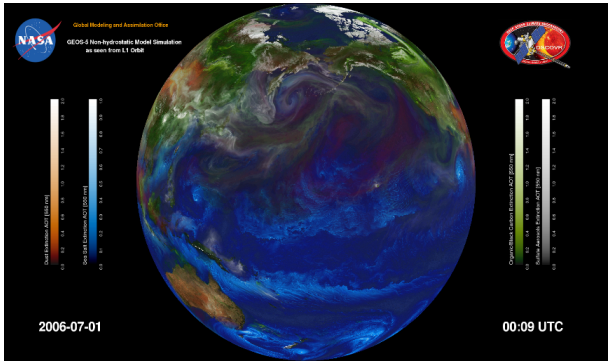
Scalable Deployment: Exploration of 3.5PB of NASA Weather/Climate Data in Real Time

Workflow

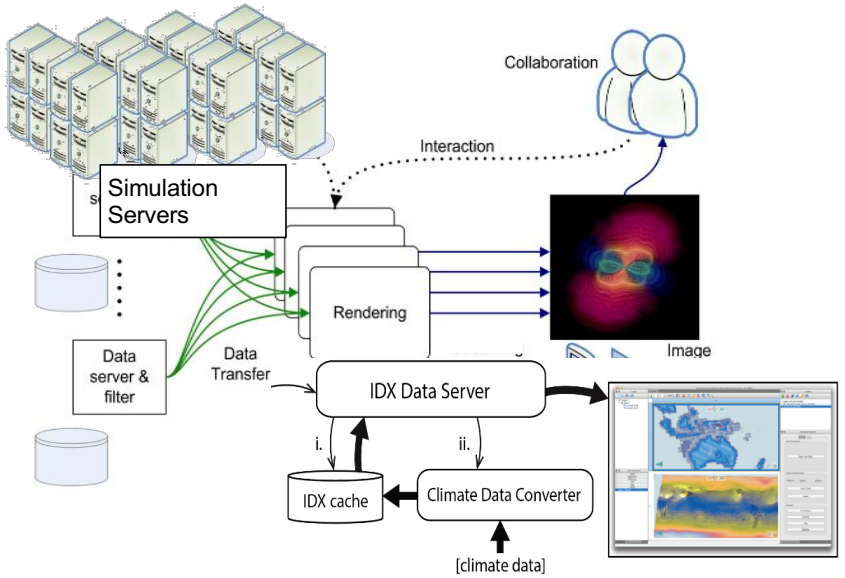
- *Data creation*
- *Data Management*
  - Processing
  - Analysis
  - Visualization

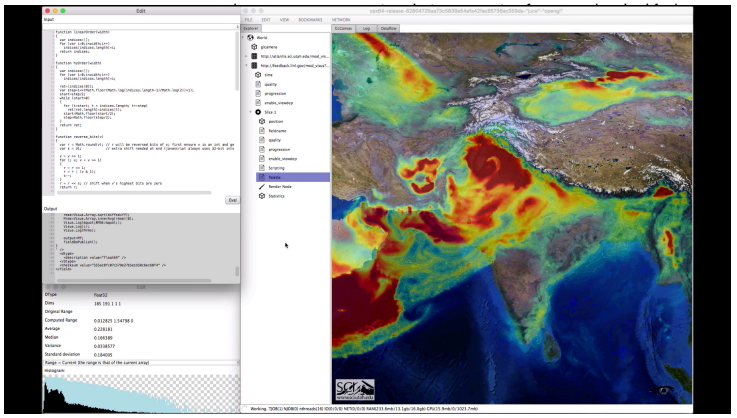


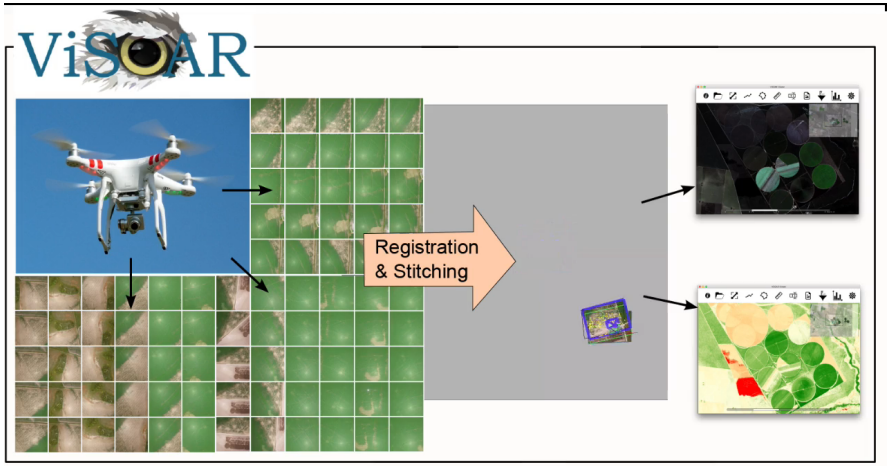
- 7km GEOS-5 “Nature Run”
- 1 dataset, 3.5 PB
- theoretically: openly accessible
- practically: precomputed pics

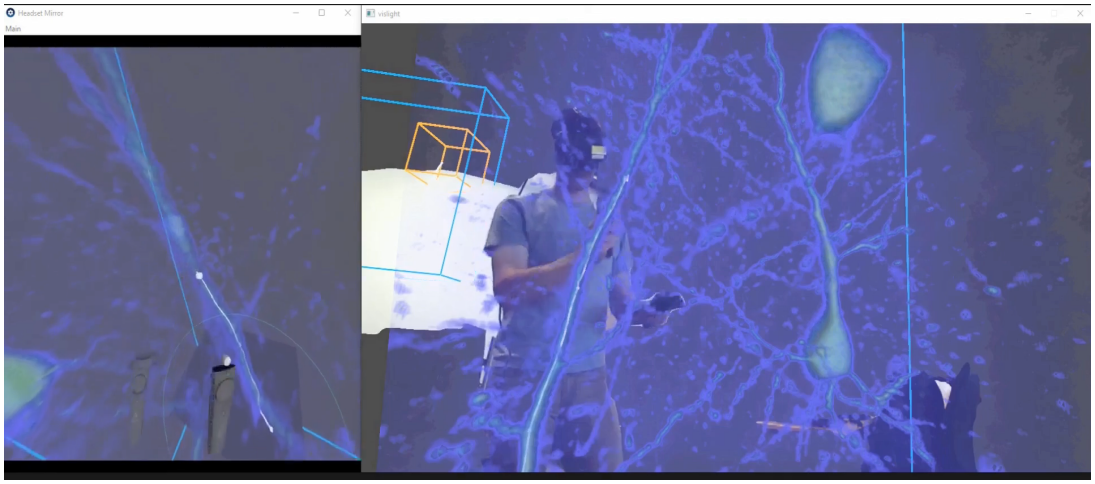
Distributed Resources

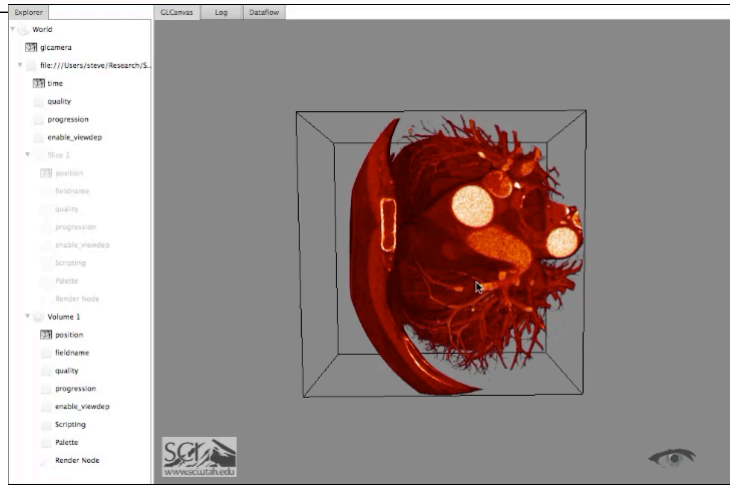
- 3.5 PB of *data store in NASA*
- *Primary ViSUS server in LLNL*
- *Secondary ViSUS server in Utah*
- *Clients connect remotely*
- *Work without additional HPC resources*

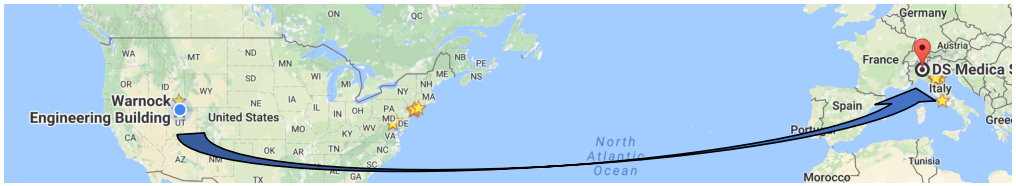





ViSOAR
Registration
& Stitching




Explorer
GLCanvas
Log
Dataflow
World
glcamera
time
quality
progression
enable_viewdep
Volume 1
position
fieldname
Scripting
Palette
Render Node


Warnock
Engineering Building
United States
North
Atlantic
Ocean
France
Germany
Austria
Italy
Spain
Tunisia
Morocco

Challenge: Graph Size

How can we deal with graphs too large to sensibly render at once?

Approach: **Path Queries and Topological Analysis**

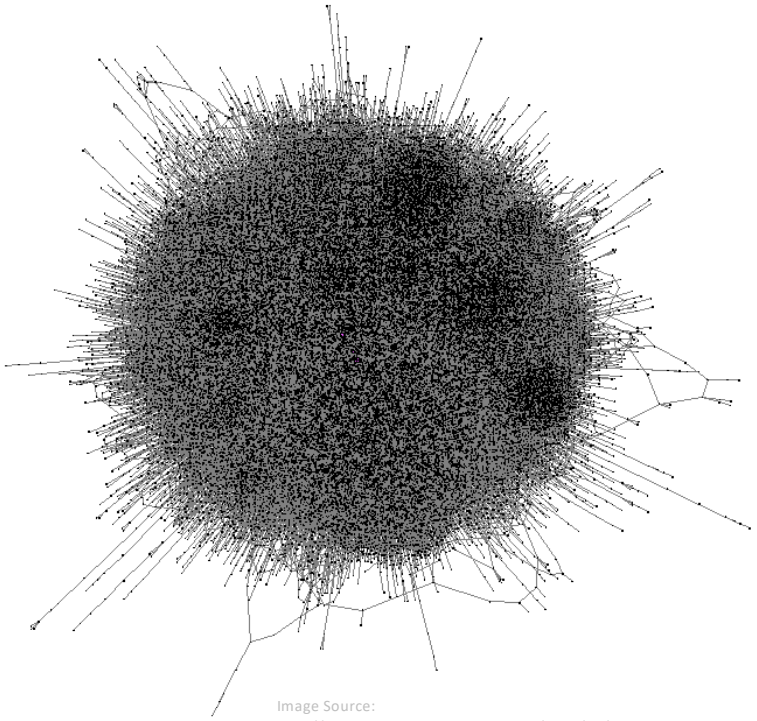


Image Source:
http://www.thenetworkthinkers.com/2013/03/big-data.html

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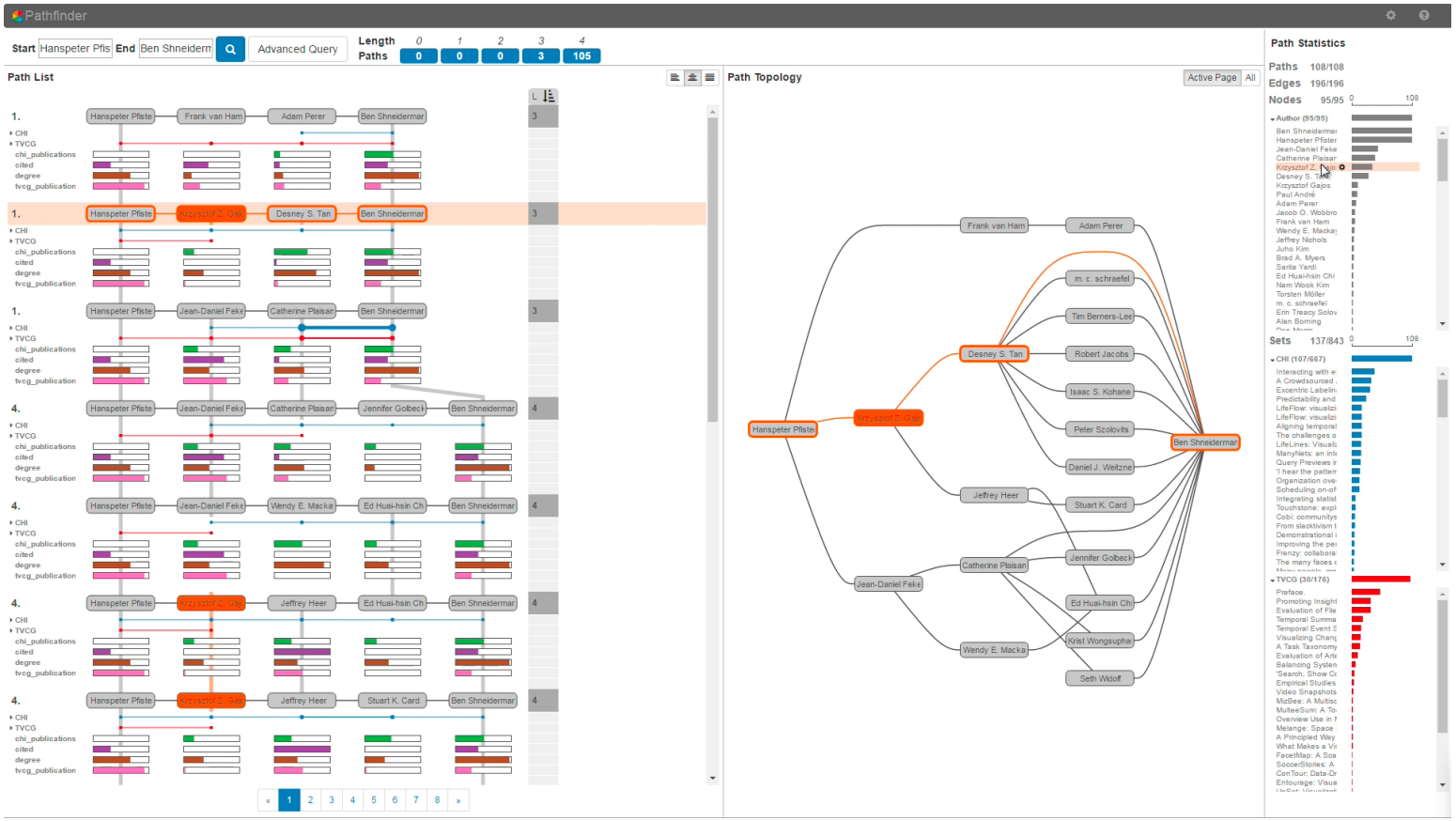
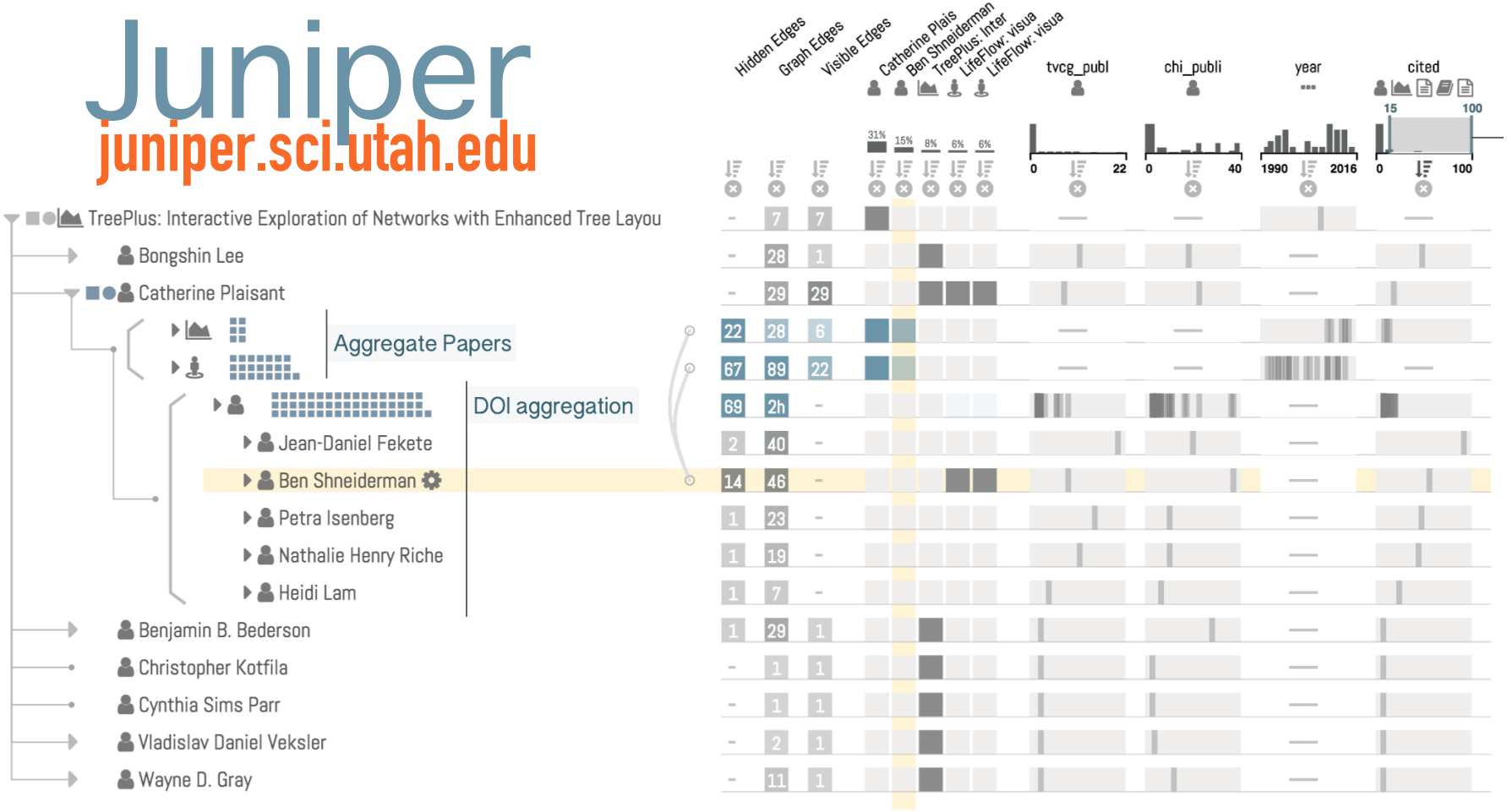
Pathfinder: Visual Analysis of Paths in Graphs



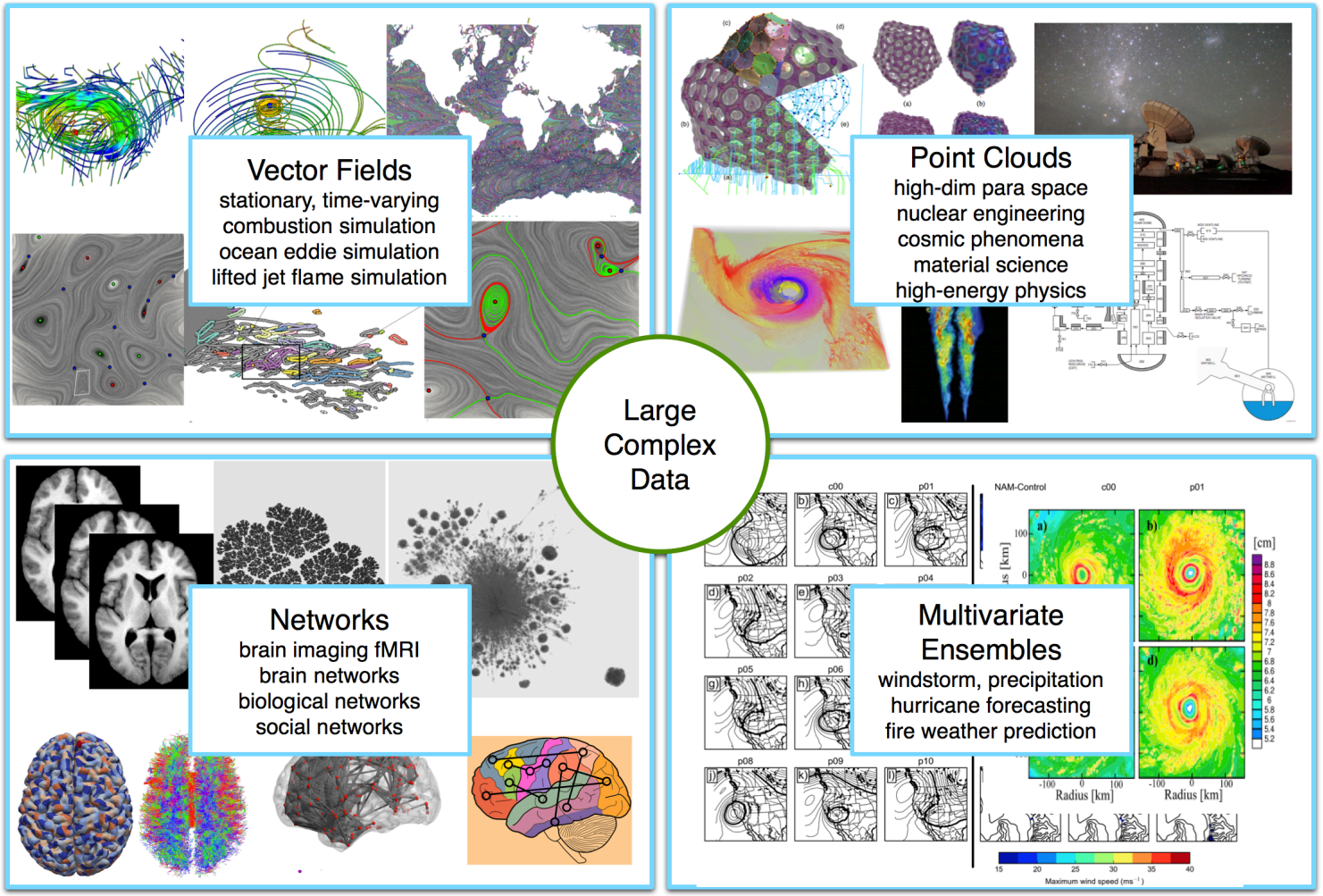
C. Partl, S. Gratzl, M. Streit, A. Wassermann, H. Pfister, D. Schmalstieg, A. Lex. **"Pathfinder: Visual Analysis of Paths in Graphs,"** In *Computer Graphics Forum (EuroVis '16)*, Vol. 35, No. 3, pp. 71-80, 2016.

Juniper

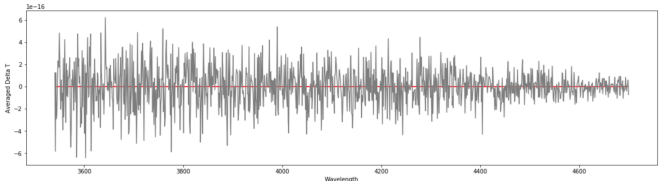
juniper.sci.utah.edu

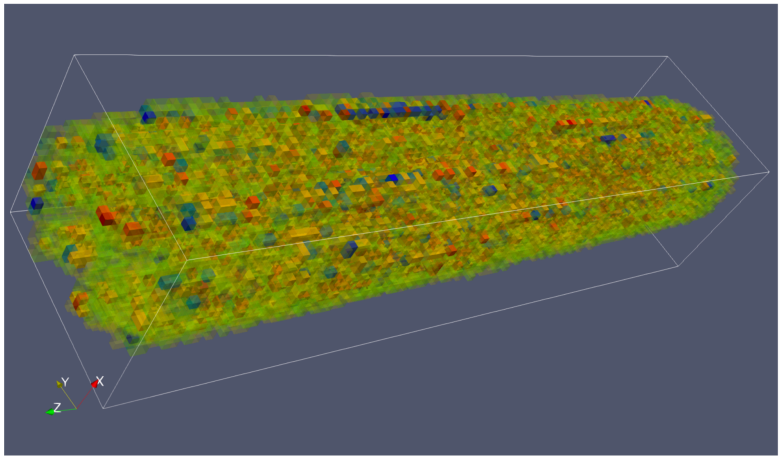


Topological Data Analysis and Visualization

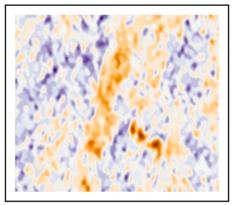


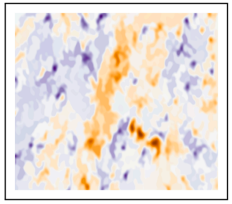
Topological Data Analysis for Astronomical Data Cubes

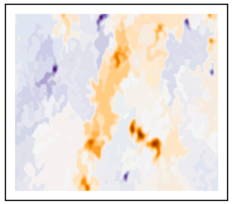


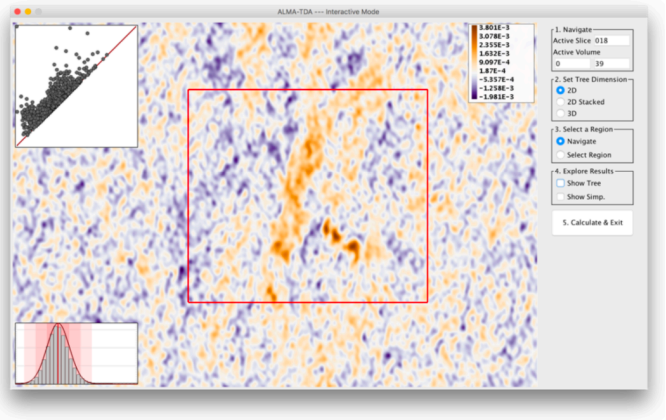


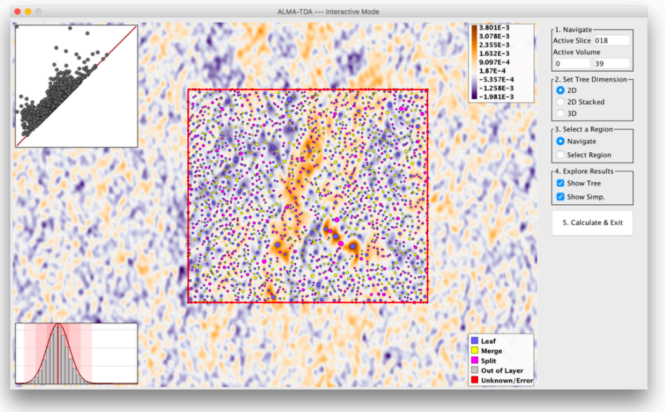
Analysis of cosmic voids







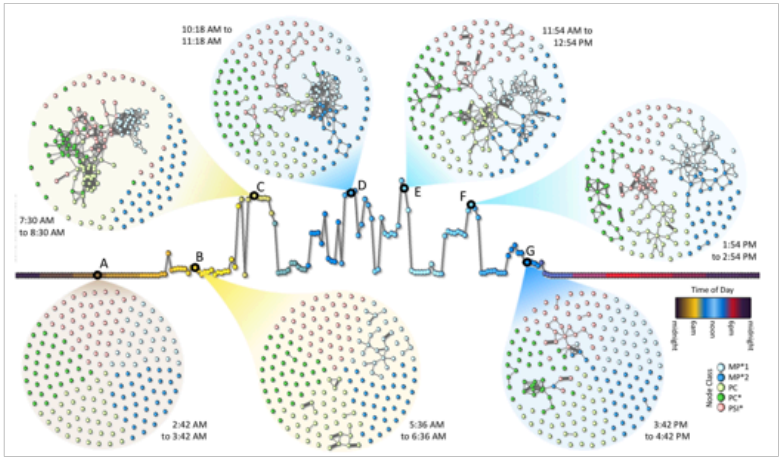


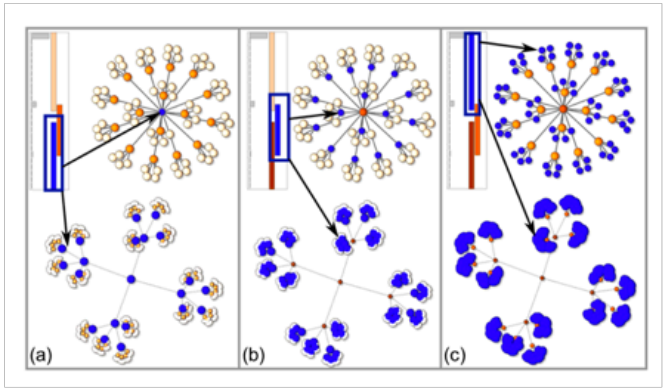


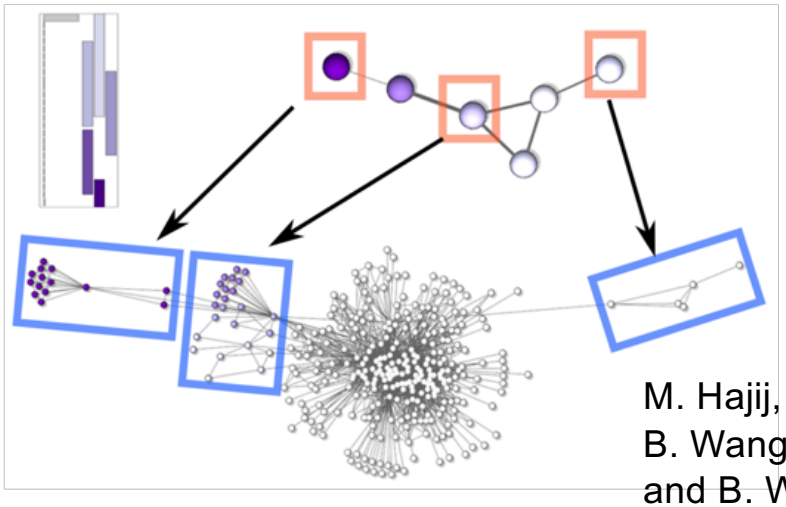
Using Contour Trees in the Analysis and Visualization of Radio Astronomy Data Cubes

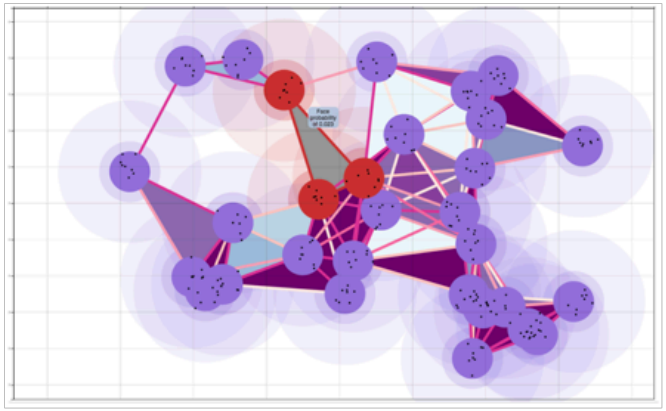
Yulong Liang, Vikranta Kamble, Helion Dumas Desbourboux, Lin Yan, Mengjiao Han, Kyle Dawson, Nicholas Boardman, Gail Zasowski, Anil Seth, Joel Brownstein, Paul Rosen, Juna A. Kollmeier, Guillermo Blanc, **Bei Wang**

Topological Analysis



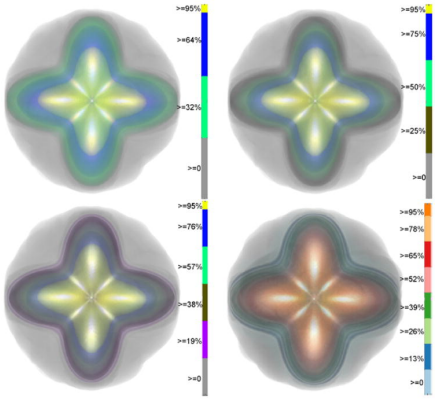


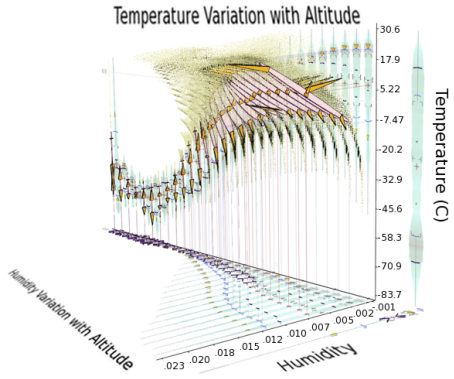




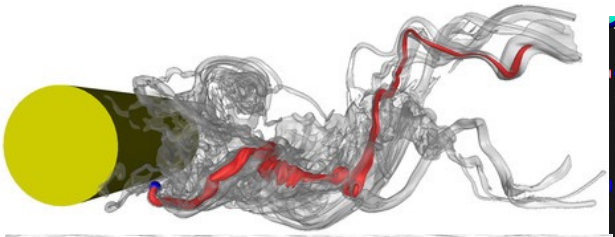
M. Hajij, B. Wang, C. Scheidegger, P. Rosen, 2018; M. Hajij, B. Wang, P. Rosen, 2018; T. Sodergren, J. Hair, J. M. Phillips and B. Wang, 2017.

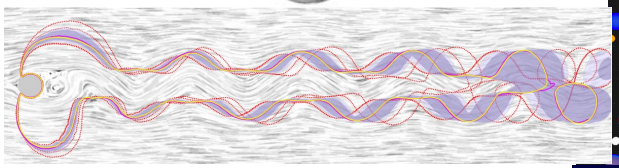
Uncertainty Visualization

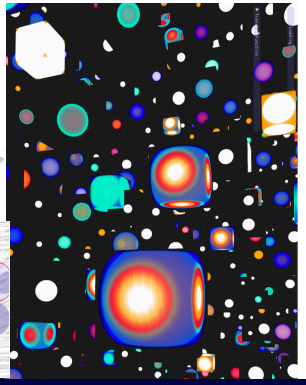


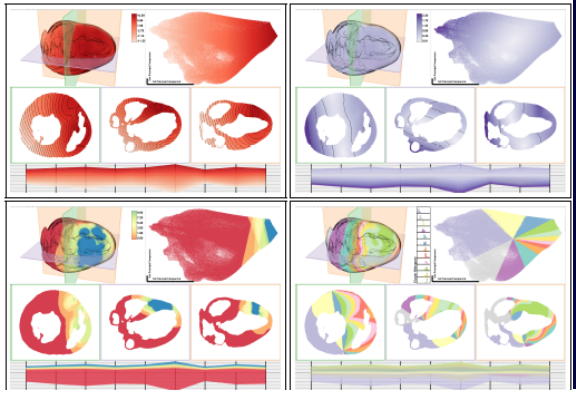


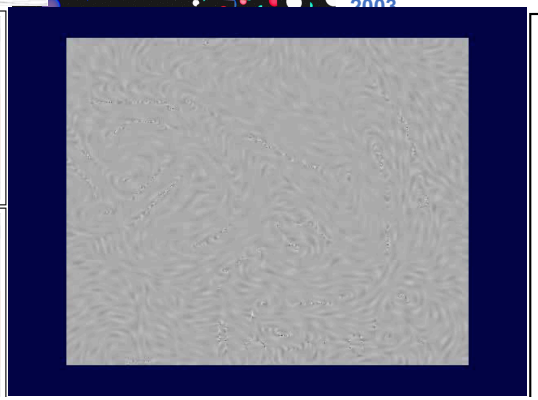
When is the last time you've seen an error bar on an isosurface?

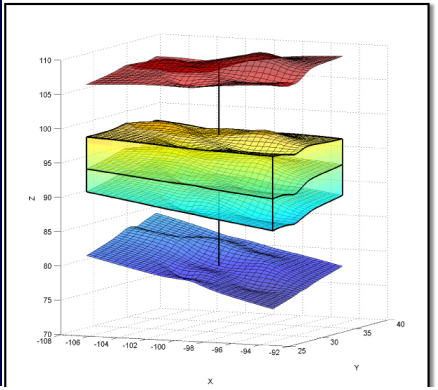












G.P. Bonneau, H.C. Hege, C.R. Johnson, M.M. Oliveira, K. Potter, P. Rheingans, T. Schultz. "Overview and State-of-the-Art of Uncertainty Visualization," In *Scientific Visualization: Uncertainty, Multifield, Biomedical, and Scalable Visualization*, Edited by M. Chen and H. Hagen and C.D. Hansen and C.R. Johnson and A. Kauffman, Springer-Verlag, pp. 3-27. 2014.

M.G. Genton, C.R. Johnson, K. Potter, G. Stenchikov, Y. Sun. "Surface boxplots," In *Stat Journal*, Vol. 3, No. 1, pp. 1-11. 2014.

K. Potter, P. Rosen, C.R. Johnson. "From Quantification to Visualization: A Taxonomy of Uncertainty Visualization Approaches," In *Uncertainty Quantification in Scientific Computing*, IFIP Series, Vol. 377, Springer, pp. 226-249. 2012.

K. Potter, A. Wilson, P.-T. Bremer, D. Williams, C. Doutriaux, V. Pascucci, C.R. Johnson. "Ensemble-Vis: A Framework for the Statistical Visualization of Ensemble Data," In *Proceedings of the 2009 IEEE International Conference on Data Mining Workshops*, pp. 233-240. 2009.

C.R. Johnson, A.R. Sanderson. "A Next Step: Visualizing Errors and Uncertainty," In *IEEE Computer Graphics and Applications*, Vol. 23, No. 5, pp. 6-10. September/October, 2003.

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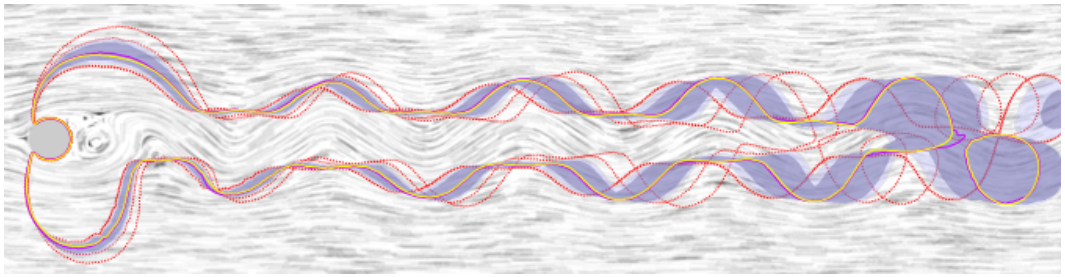
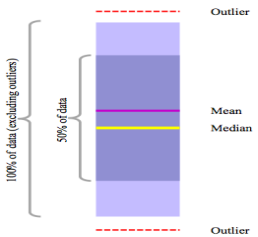
Contour Box Plots

$$S \in \mathrm{sB}\left(S_1, \ldots S_j\right) \iff \bigcap_{k=1}^{j} S_k \subset S \subset \bigcup_{k=1}^{j} S_k.$$





Whitaker, Mirzargar, Kirby, *IEEE Transactions on Visualization and Computer Graphics*, Vol. 19, No. 12, pp. 2713--2722, 2013.

M.G. Genton, C.R. Johnson, K. Potter, G. Stenchikov, Y. Sun. "Surface boxplots," In *Stat Journal*, Vol. 3, No. 1, pp. 1-11. 2014.

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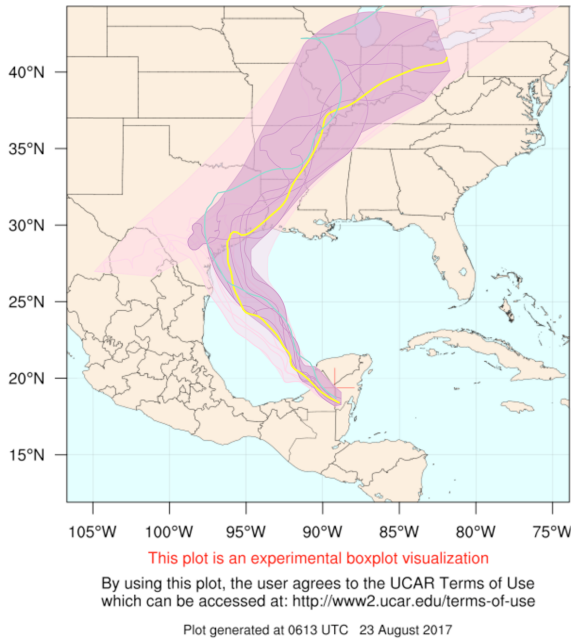
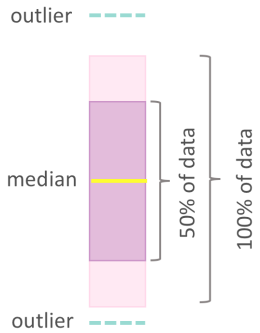
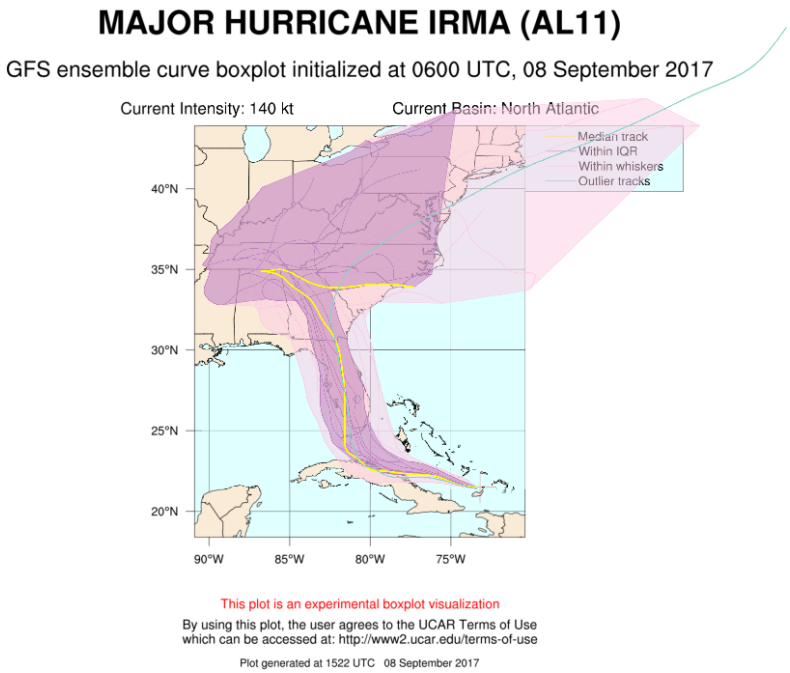
Ensemble Curved Boxplot







NCAR

M. Mirzargar, R. Whitaker, R. M. Kirby. "Curve Boxplot: Generalization of Boxplot for Ensembles of Curves," IEEE Transactions on Visualization and Computer Graphics, Vol. 20, No. 12, IEEE, pp. 2654-63. December, 2014.

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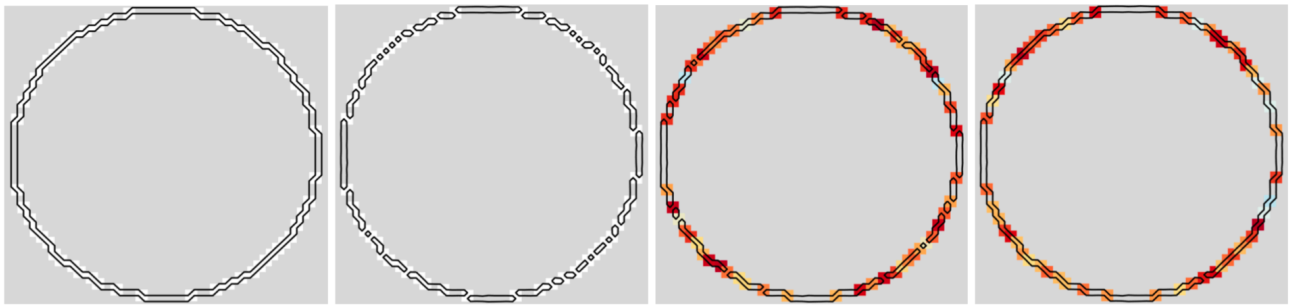
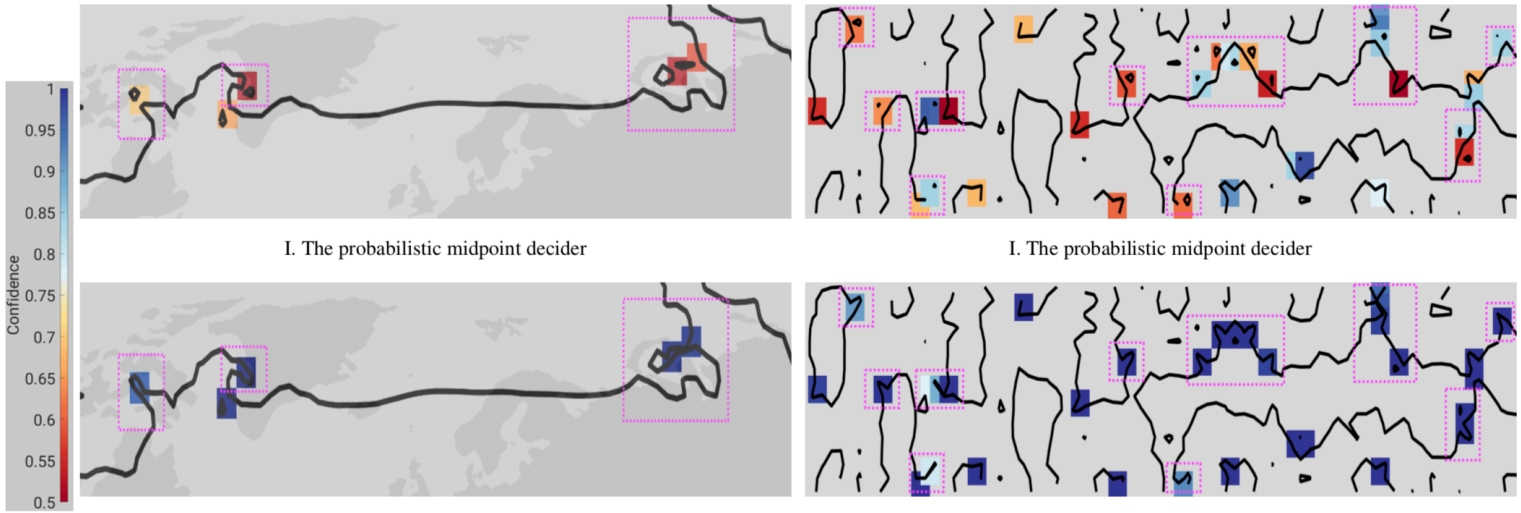
Probabilistic Asymptotic Decider for Topological Ambiguity Resolution in Level-Set Extraction for Uncertain 2D Data

Tushar Athawale and Chris R. Johnson



(a) The isocontour topology in the (b) The asymptotic decider in the mean (c) The probabilistic midpoint decider (d) The probabilistic asymptotic decider



I. The probabilistic midpoint decider

I. The probabilistic midpoint decider

II. The probabilistic asymptotic decider

II. The probabilistic asymptotic decider

(a) The temperature field

(b) The velocity field for the Kàrmàn vortex street

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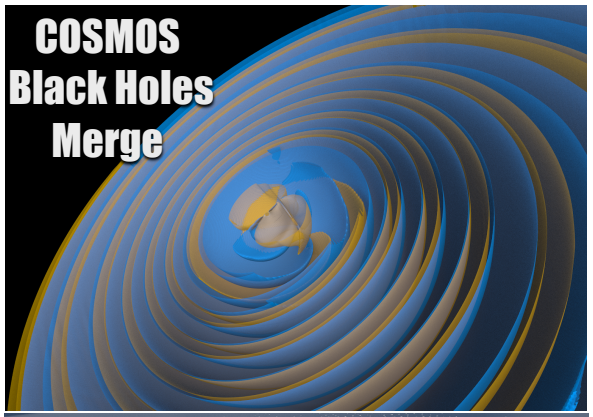
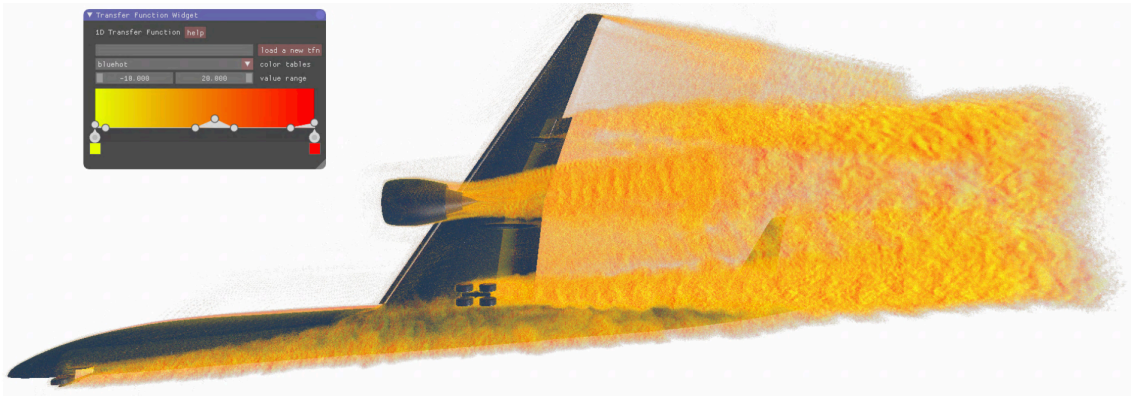
AMR Data Visualization

- Block-structured AMR



NASA LandingGear

- Tree-based (unstructured) AMR



NASA Exajet

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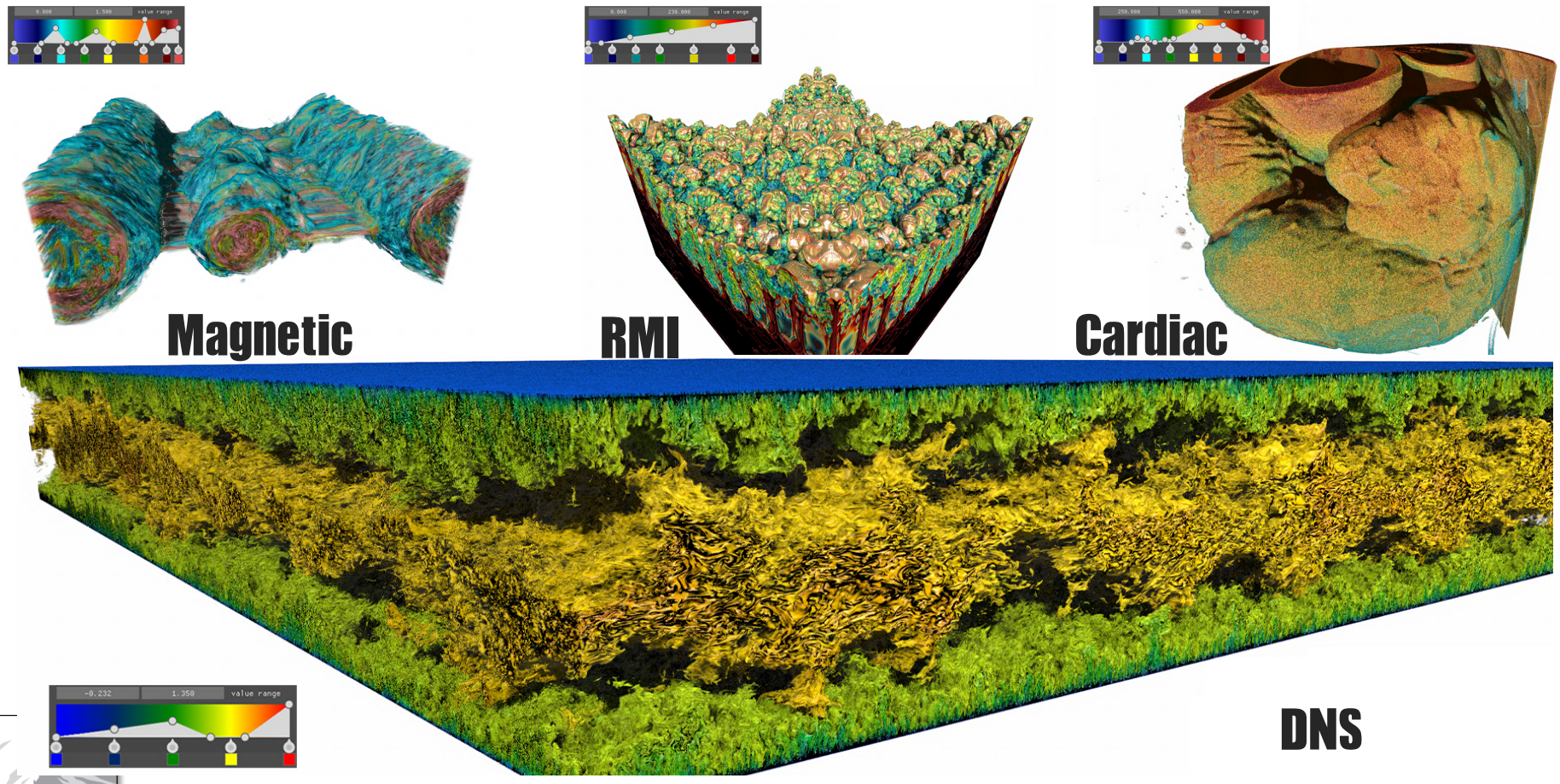
Interactive Visualization of Large-Scale Datasets



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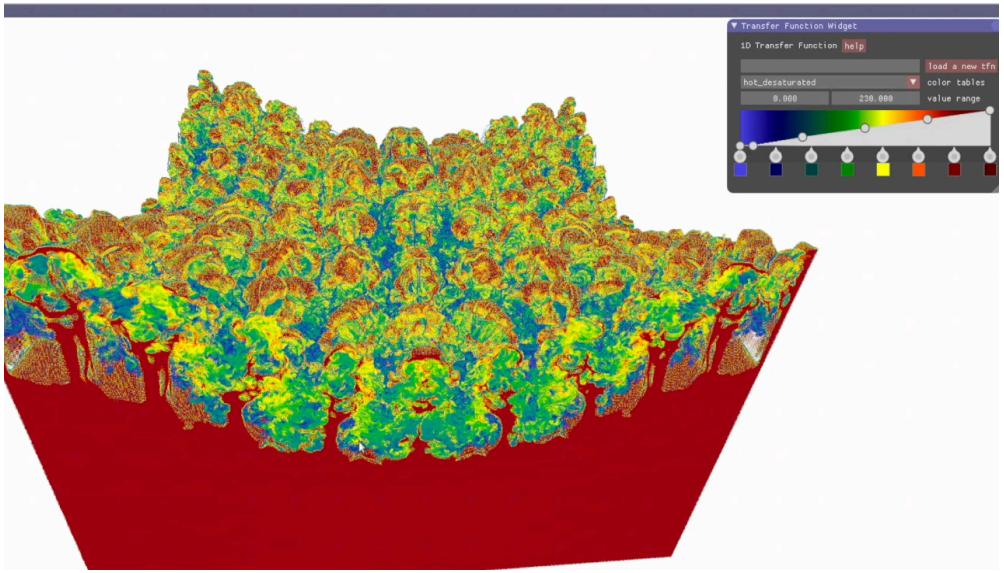
Ray-guided Progressive Rendering

Progressive sampling

- Hierarchical representation
- On-demand loading
- Independent data-streaming threads
- Visualize coarse data as a approximate and gradually refine it



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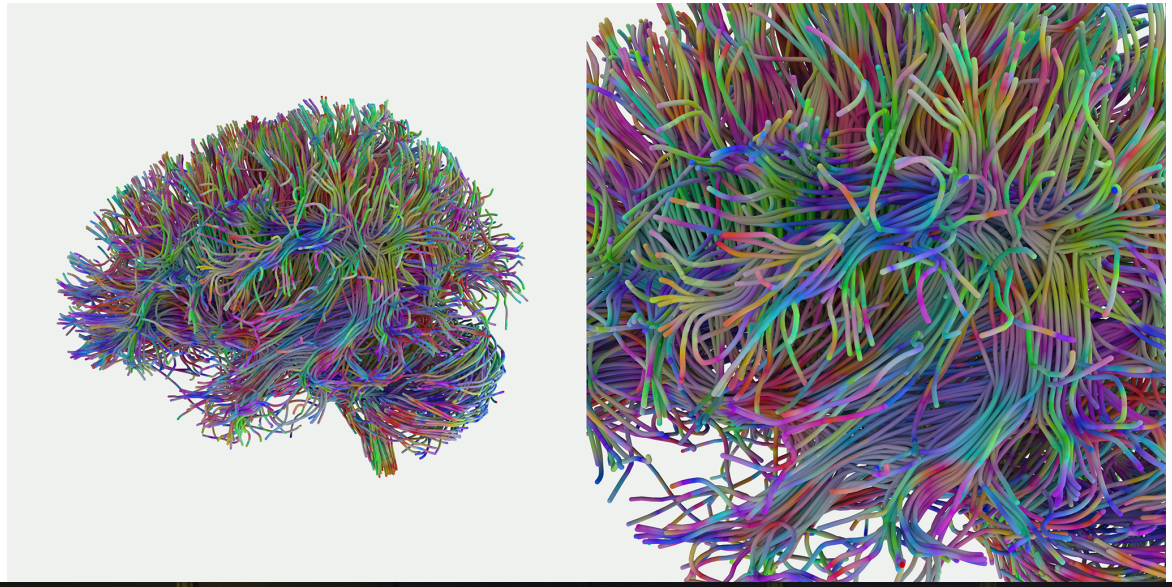

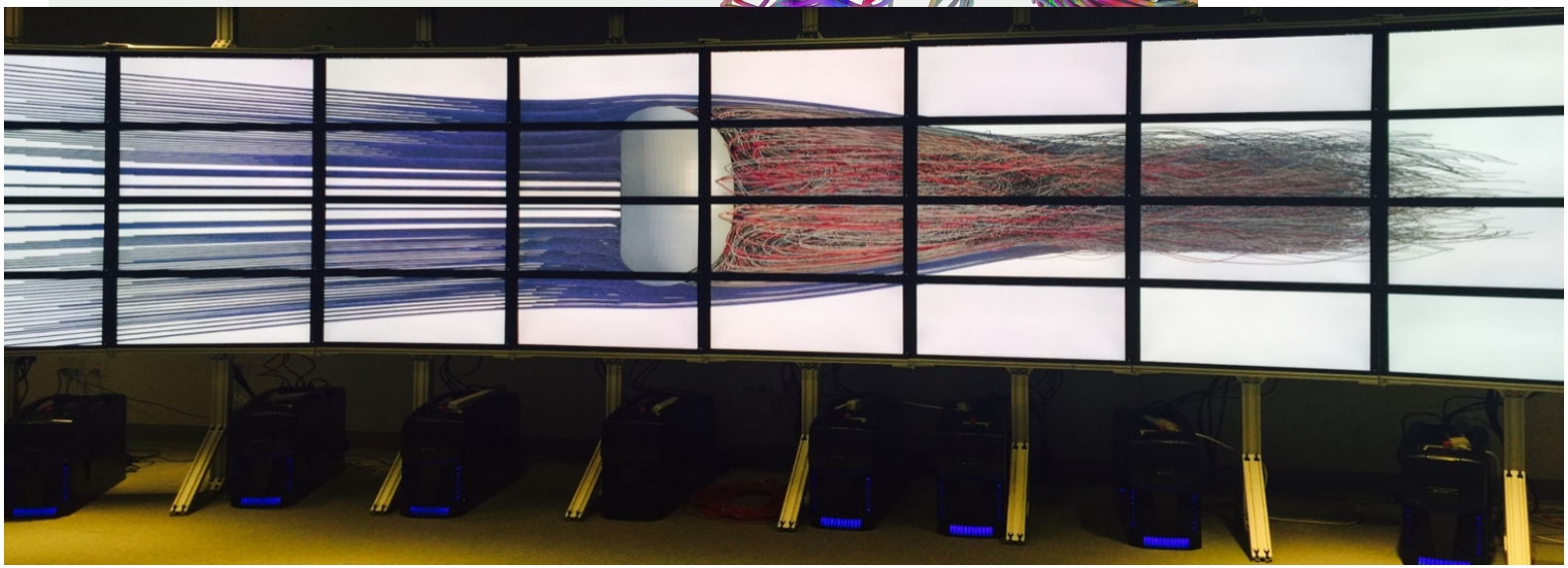

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Interactive Streamline Exploration and Manipulation using Deformation

Xin Tong[1], John Edwards[2], Chun-Ming Chen[1],
Han-Wei Shen[1], Chris R. Johnson[2], Pak Chung Wong[3]
[1]The Ohio State University
[2]Scientific Computing and Imaging Institute, University of Utah
[3]Pacific Northwest National Laboratory

Productivity Machines

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