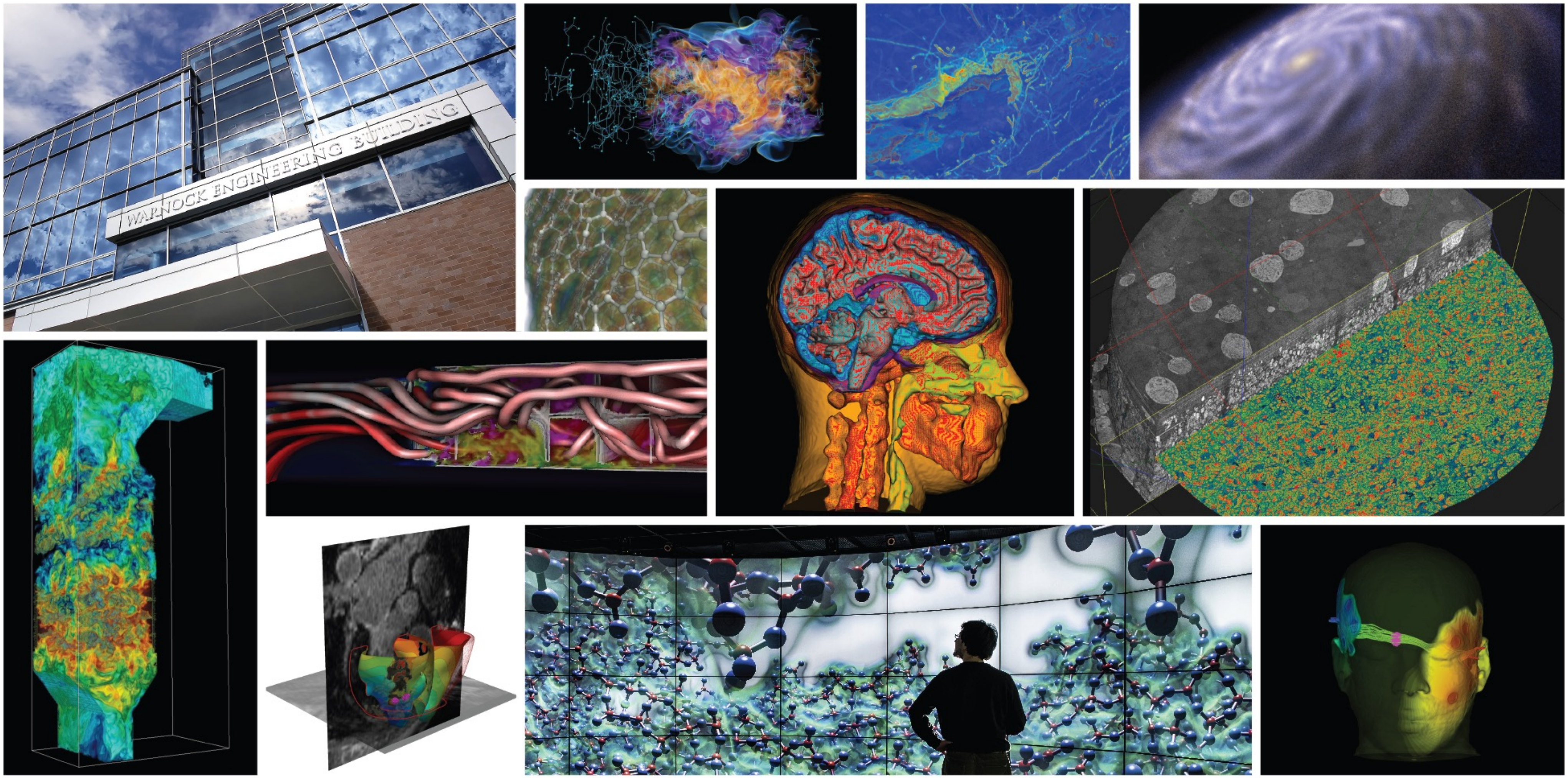
Visual Analysis in the Age of Data



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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SCI Institute Family

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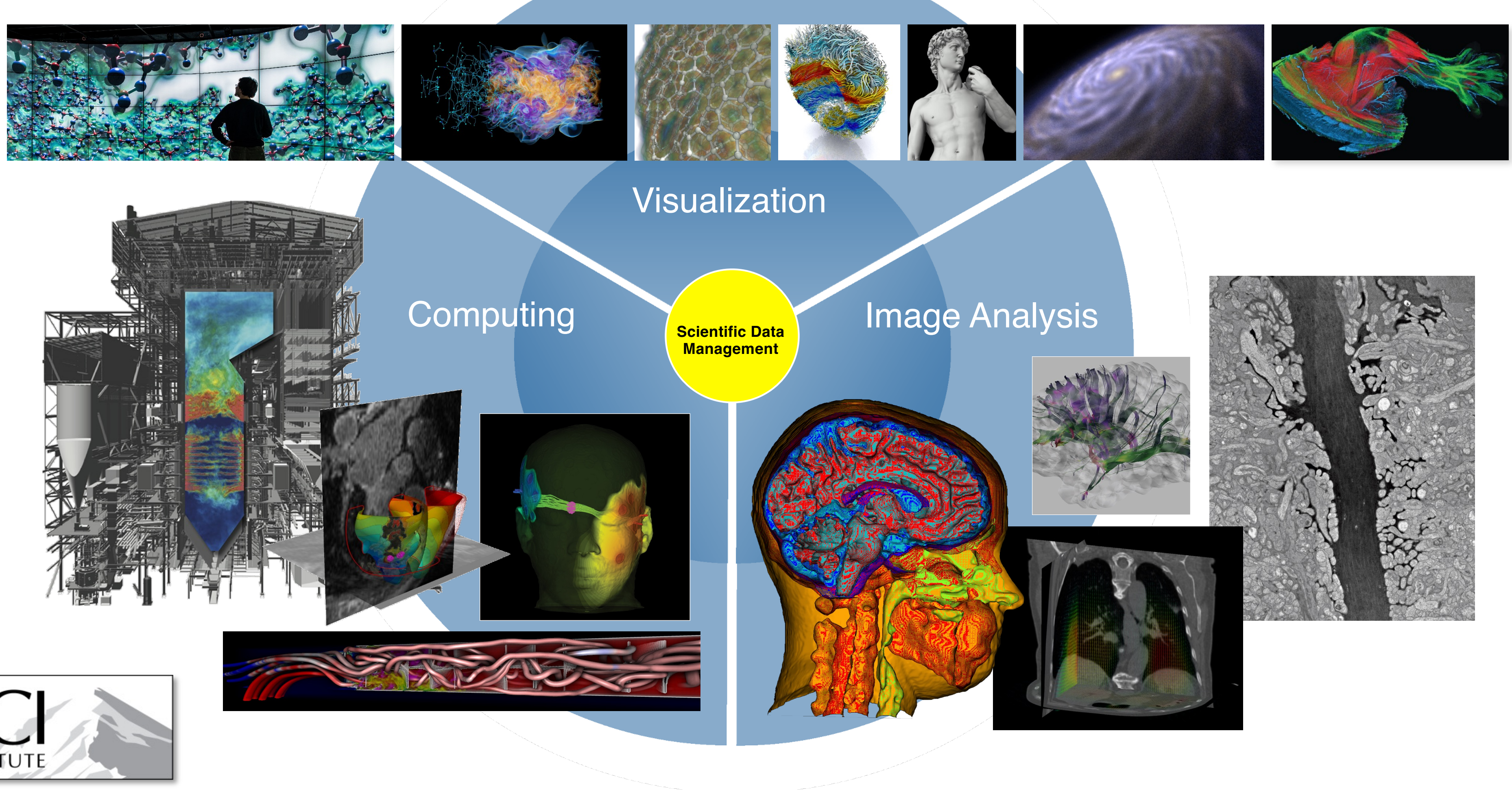
Research Cores



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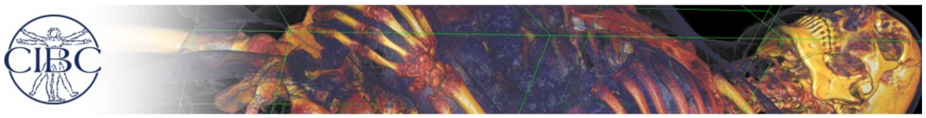
Centers We Direct

NIH/NIGMS Center for Integrative Biomedical Computing



CEDMAV
UNIVERSITY OF UTAH
CENTER FOR EXTREME DATA MANAGEMENT, ANALYSIS, AND VISUALIZATION

intel
Graphics and Visualization Institute

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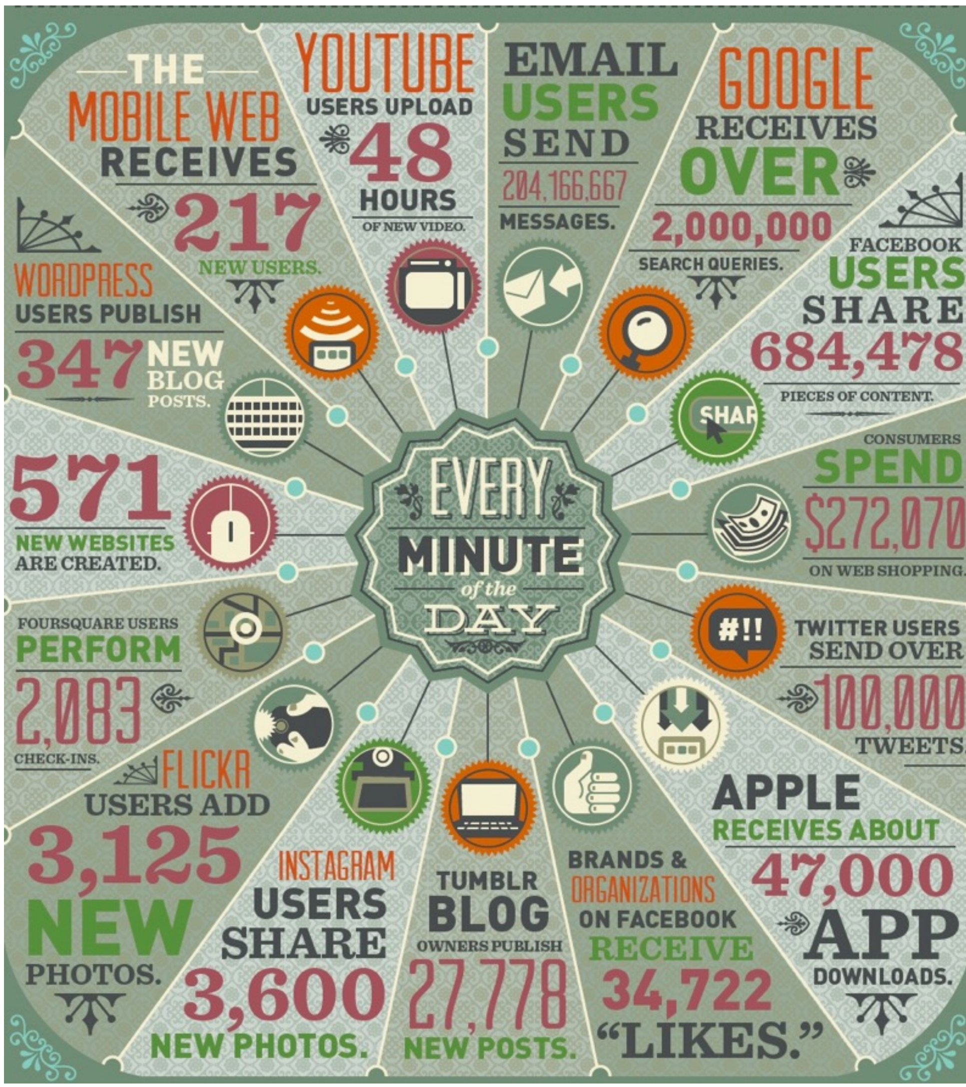
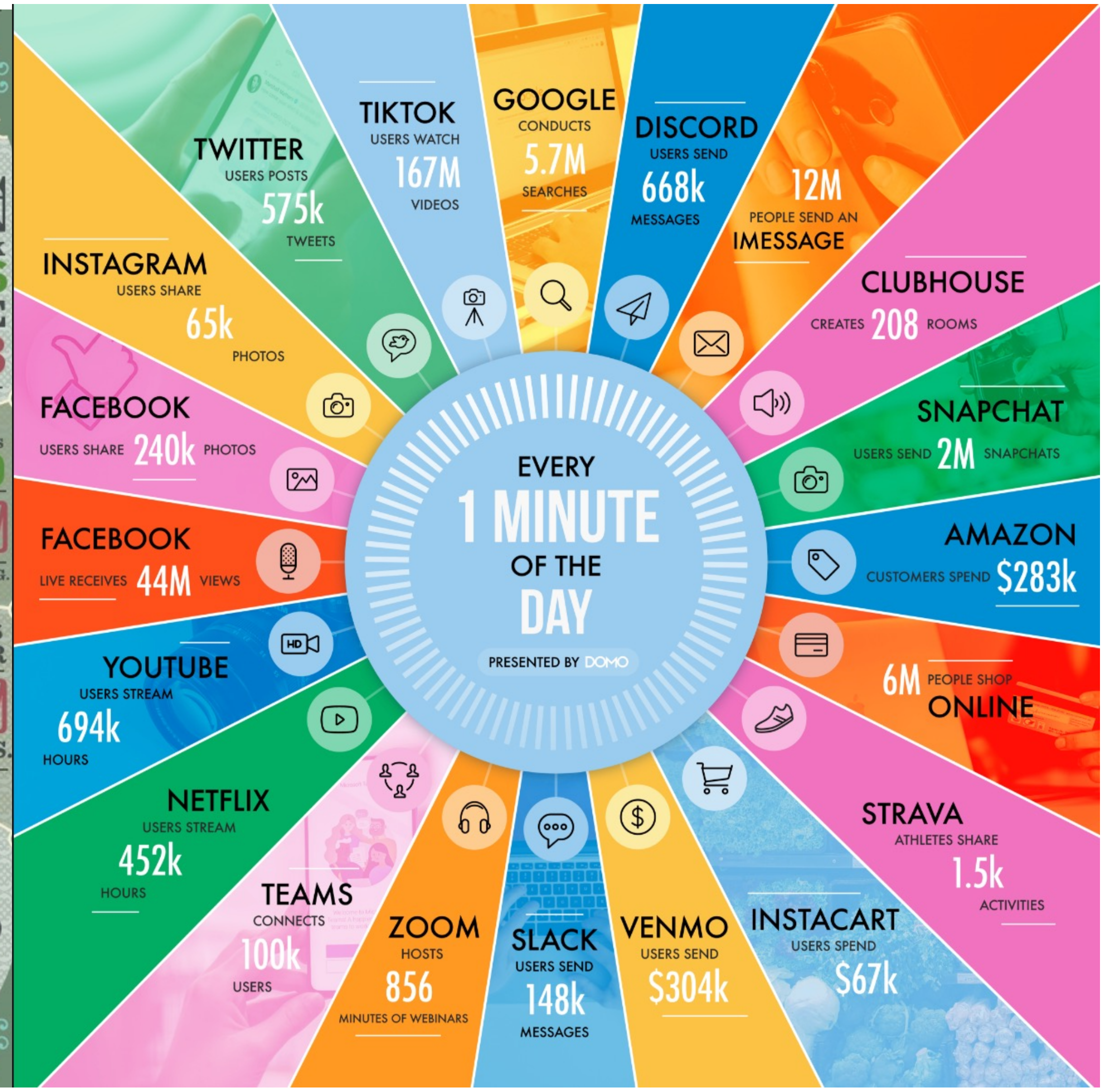


EVERY MINUTE of the DAY
THE MOBILE WEB RECEIVES 217 NEW USERS.
YOUTUBE USERS UPLOAD 48 HOURS OF NEW VIDEO.
EMAIL USERS SEND 204,166,667 MESSAGES.
GOOGLE RECEIVES OVER 2,000,000 SEARCH QUERIES.
FACEBOOK USERS SHARE 684,478 PIECES OF CONTENT.
CONSUMERS SPEND $272,070 ON WEB SHOPPING.
TWITTER USERS SEND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



EVERY 1 MINUTE OF THE DAY
PRESENTED BY DOMO
TWITTER USERS POSTS 575k TWEETS
TIKTOK USERS WATCH 167M VIDEOS
GOOGLE CONDUCTS 5.7M SEARCHES
DISCORD USERS SEND 668k MESSAGES
12M PEOPLE SEND AN IMESSAGE
CLUBHOUSE CREATES 208 ROOMS
SNAPCHAT USERS SEND 2M SNAPCHATS
AMAZON CUSTOMERS SPEND $283k
6M PEOPLE SHOP ONLINE
STRAVA ATHLETES SHARE 1.5k ACTIVITIES
INSTACART USERS SPEND $67k
VENMO USERS SEND $304k
SLACK USERS SEND 148k MESSAGES
ZOOM HOSTS 856 MINUTES OF WEBINARS
TEAMS CONNECTS 100k USERS
NETFLIX USERS STREAM 452k HOURS
YOUTUBE USERS STREAM 694k HOURS
FACEBOOK LIVE RECEIVES 44M VIEWS
FACEBOOK USERS SHARE 240k PHOTOS
INSTAGRAM USERS SHARE 65k PHOTOS

Brain Information Bandwidth

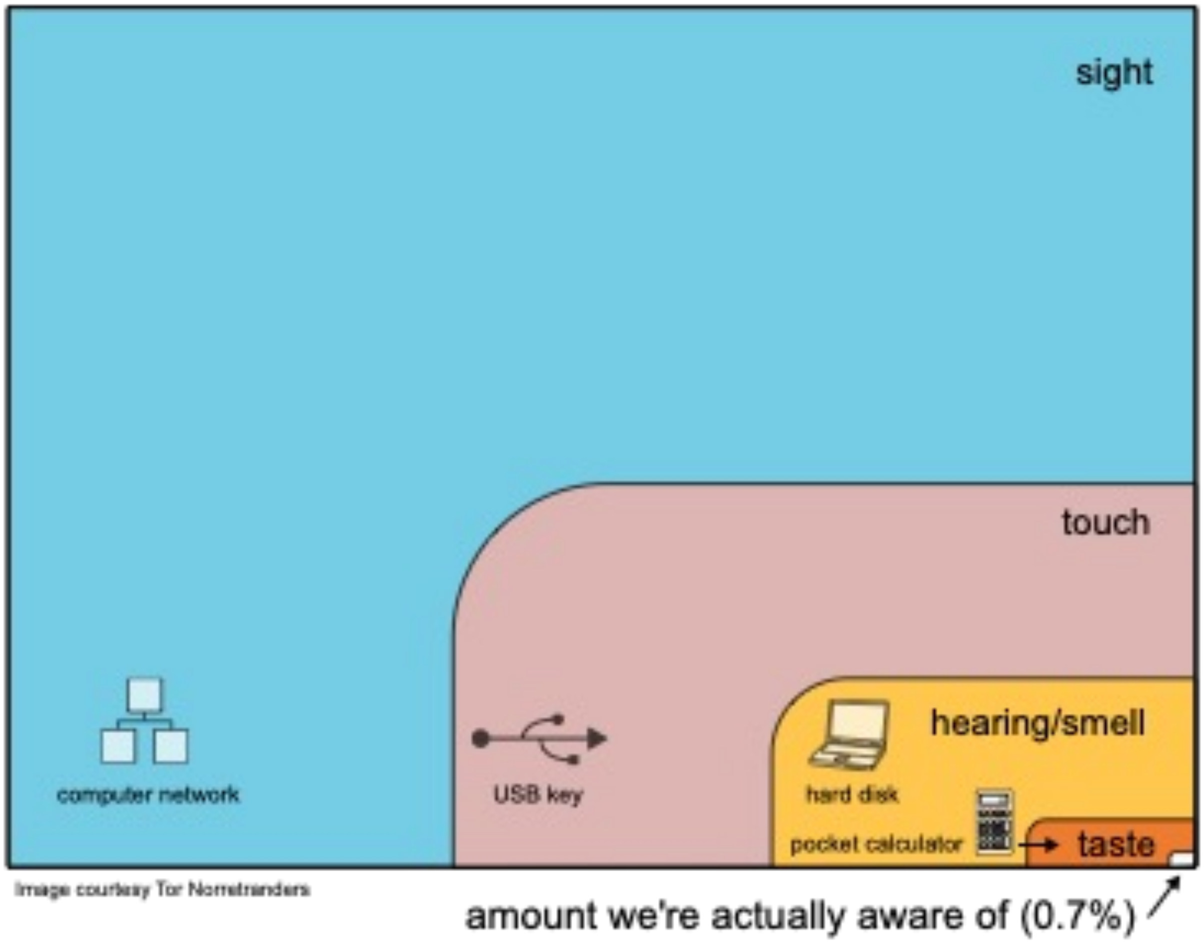
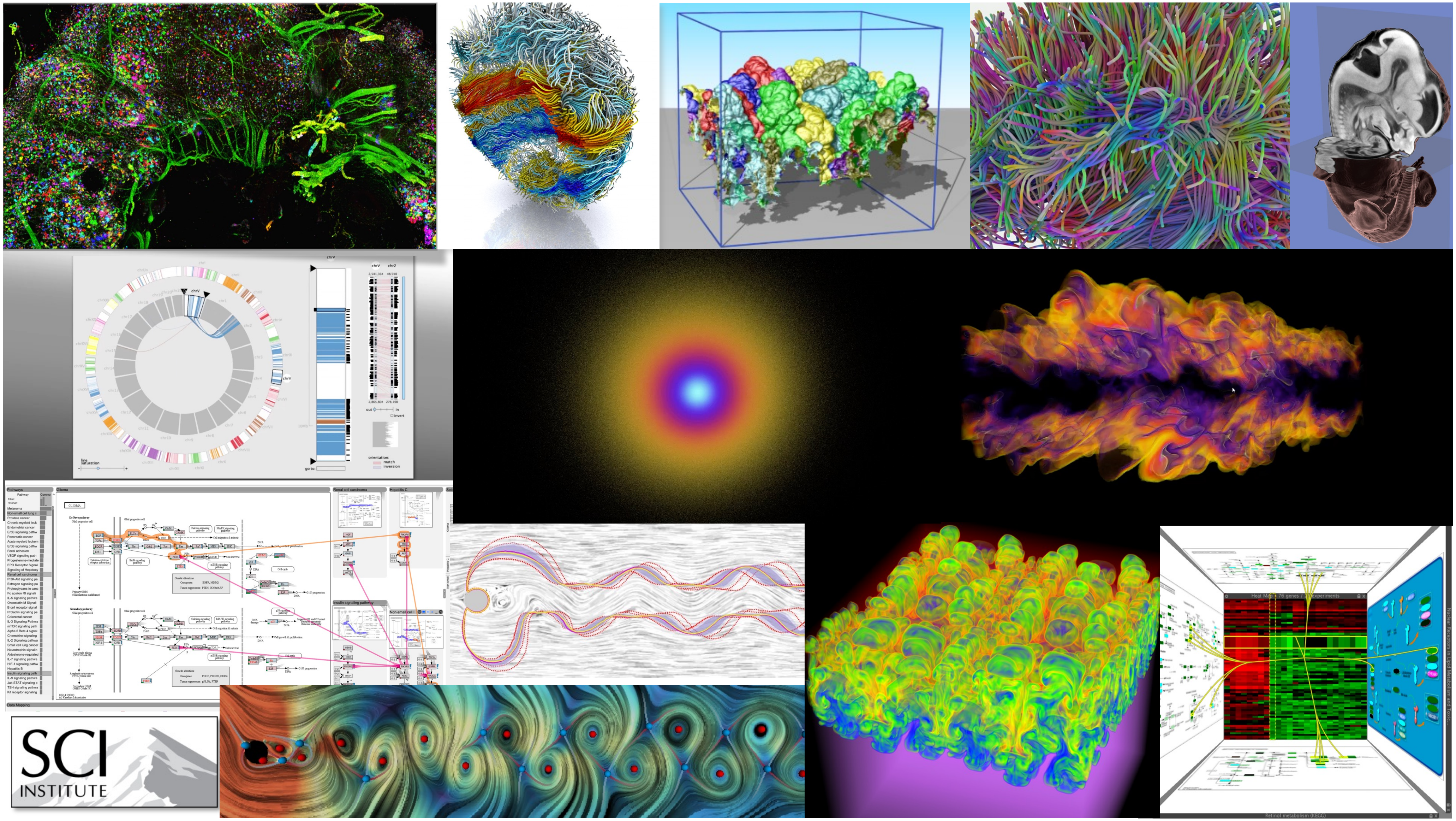


Image courtesy Tor Norretranders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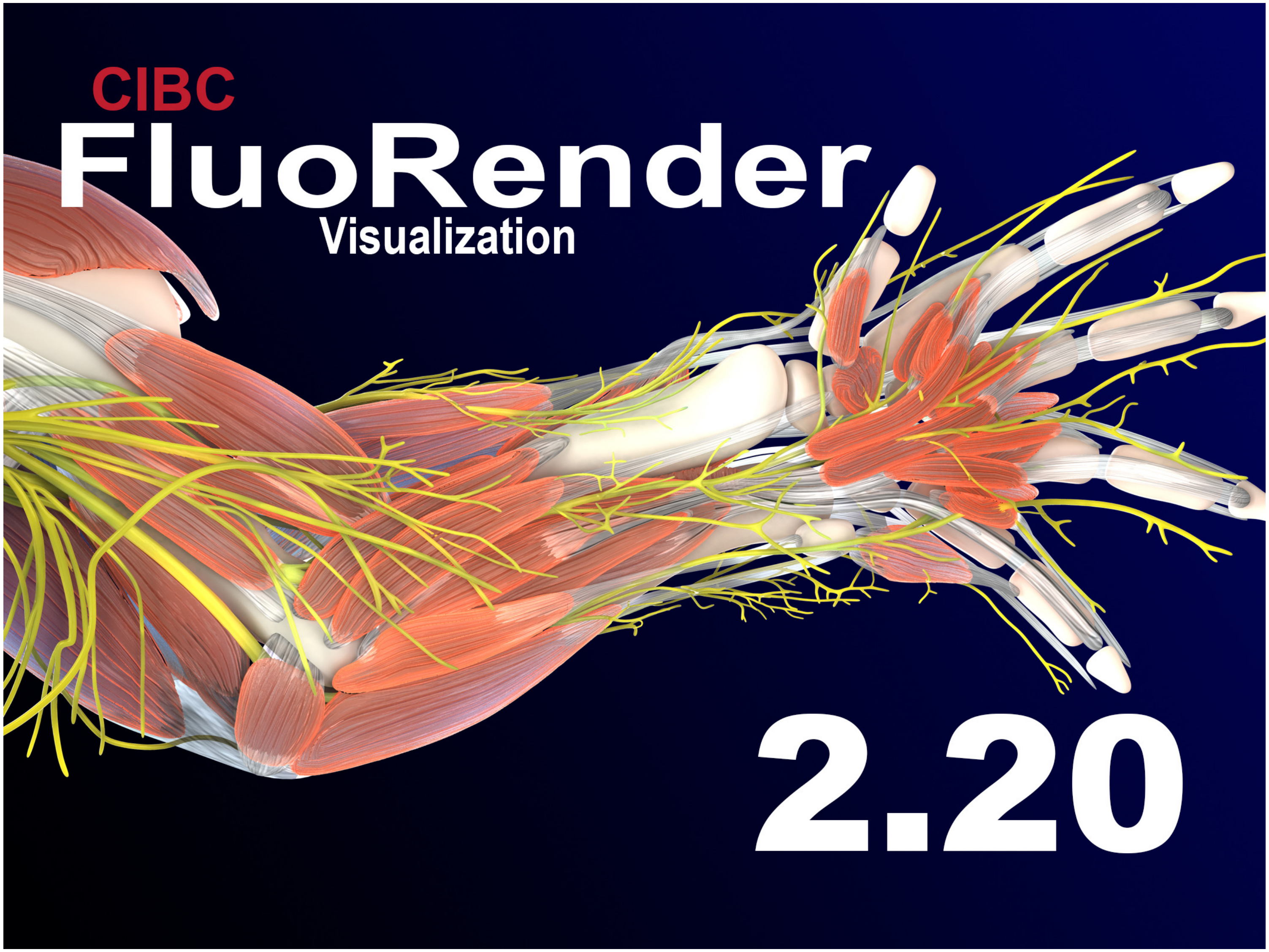

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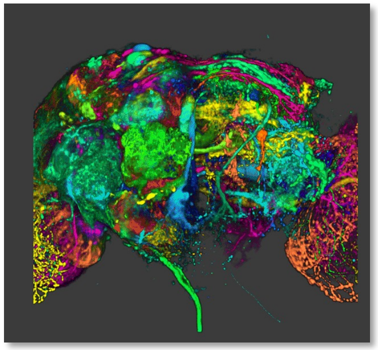
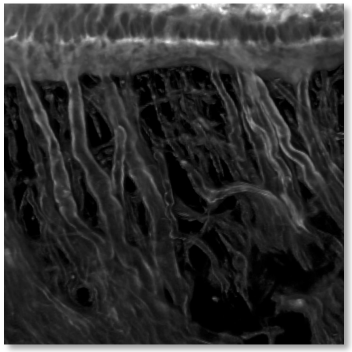
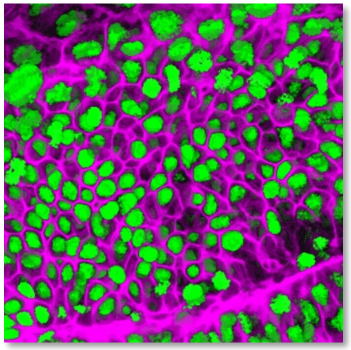
FluoRender Capabilities



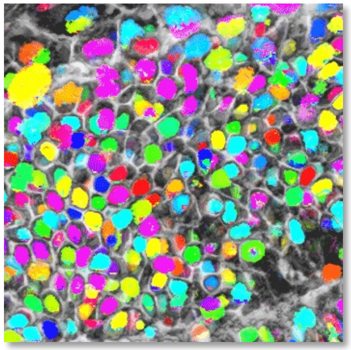
Multichannel visualization



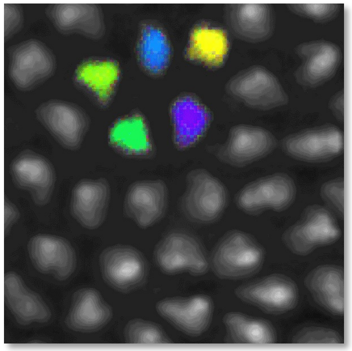
Interactive segmentation



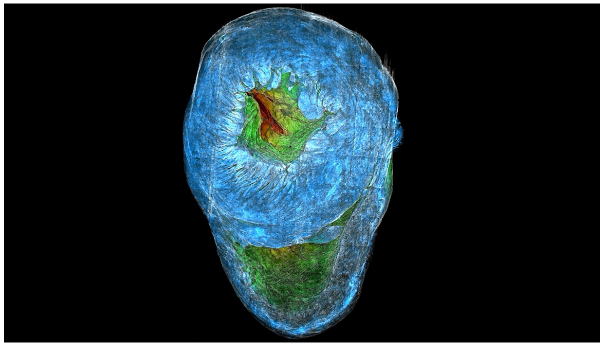
4D scan visualization



Auto segmentation on GPU



Tracking

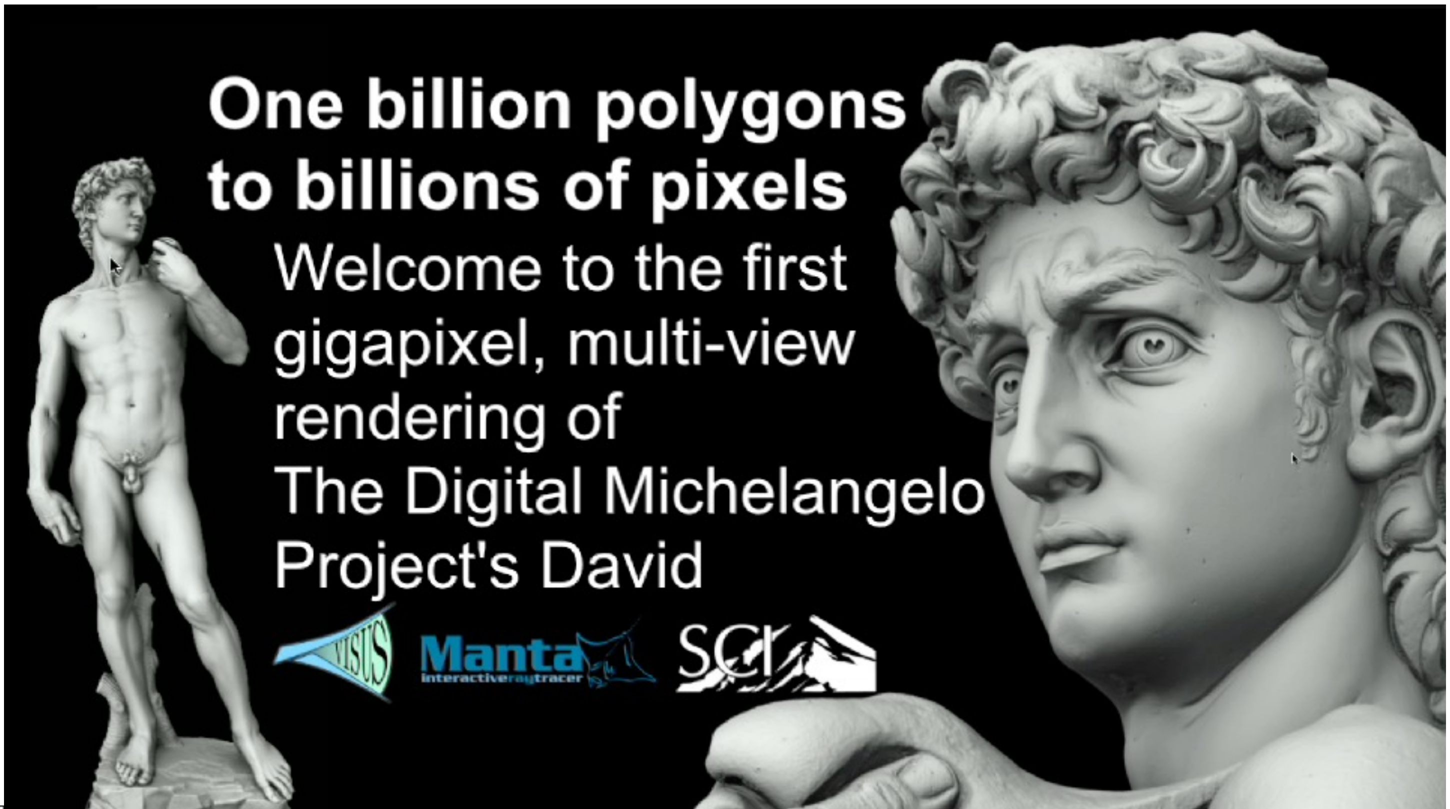


Large-Scale Data

FluoRender

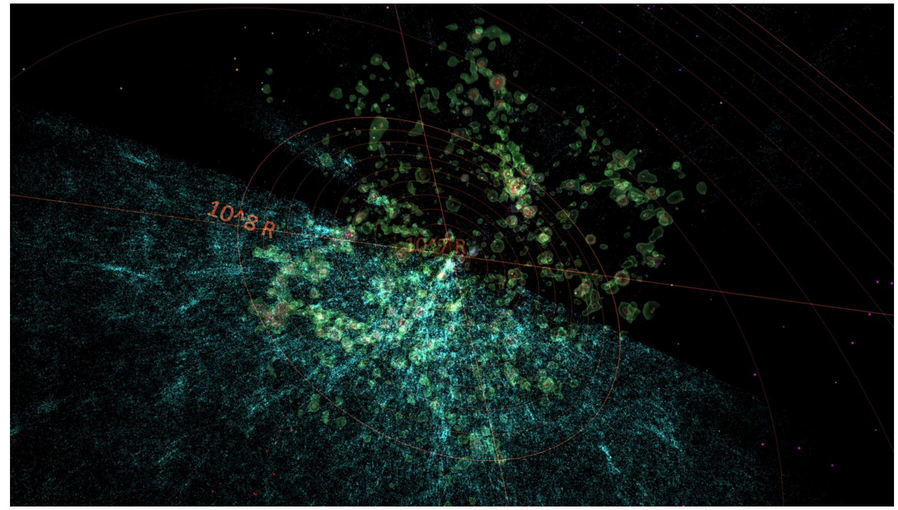
Michelangelo's David

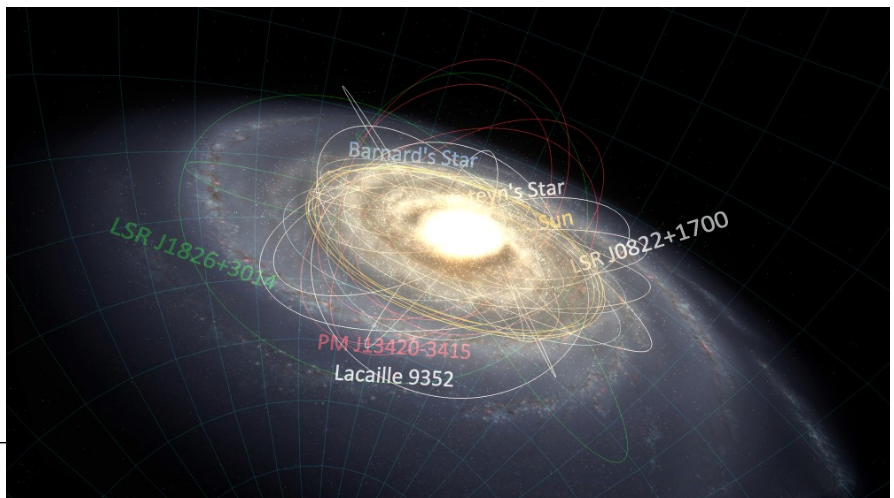
Michelangelo's David - Part 2



OpenSpace

Platform for:
- **Visualization Research**
- **Space & Astro Research**
- **Science Communication**





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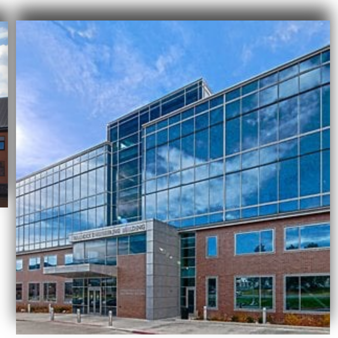
OpenSpace Team



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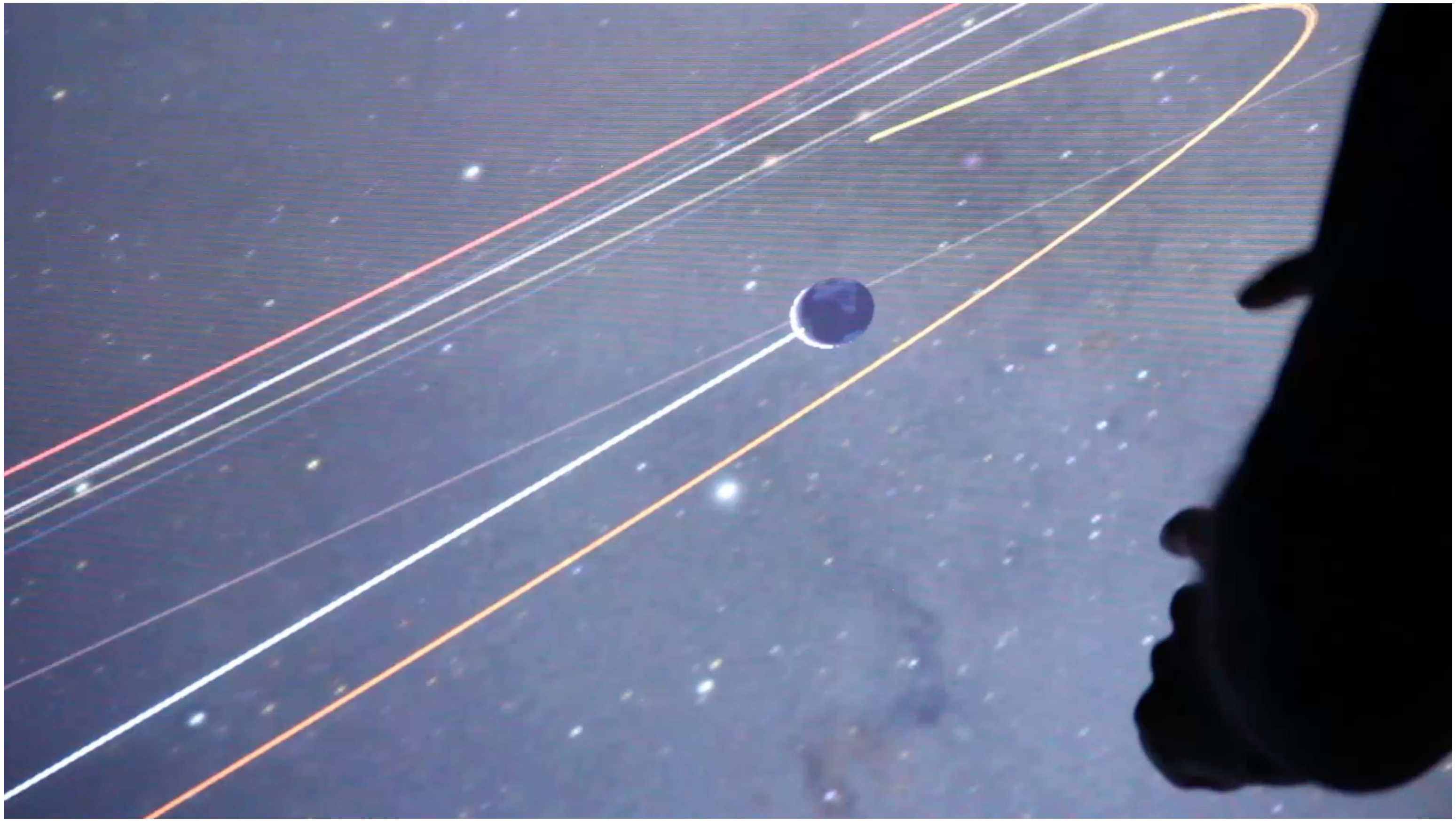
http://openspaceproject.com



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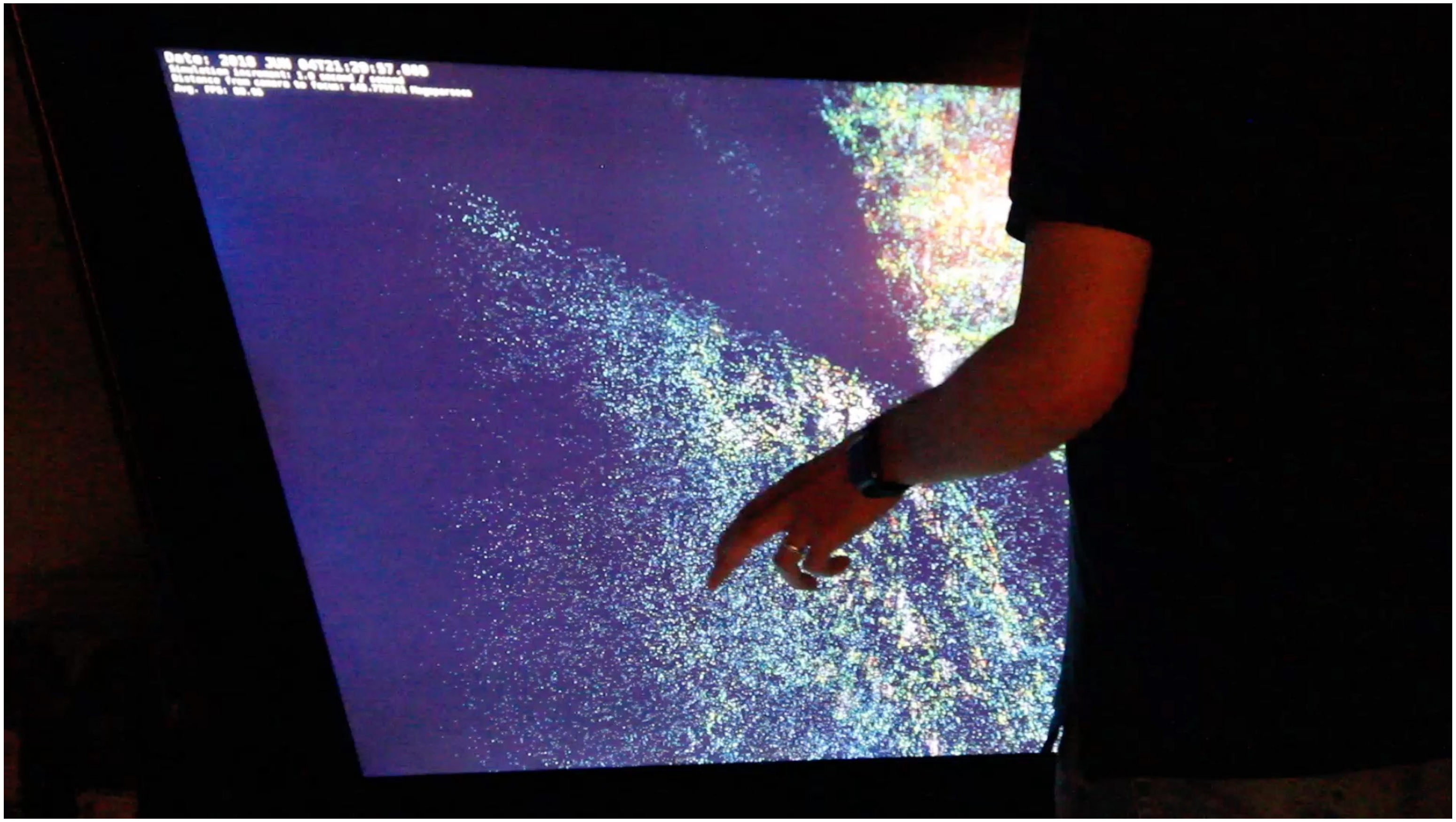

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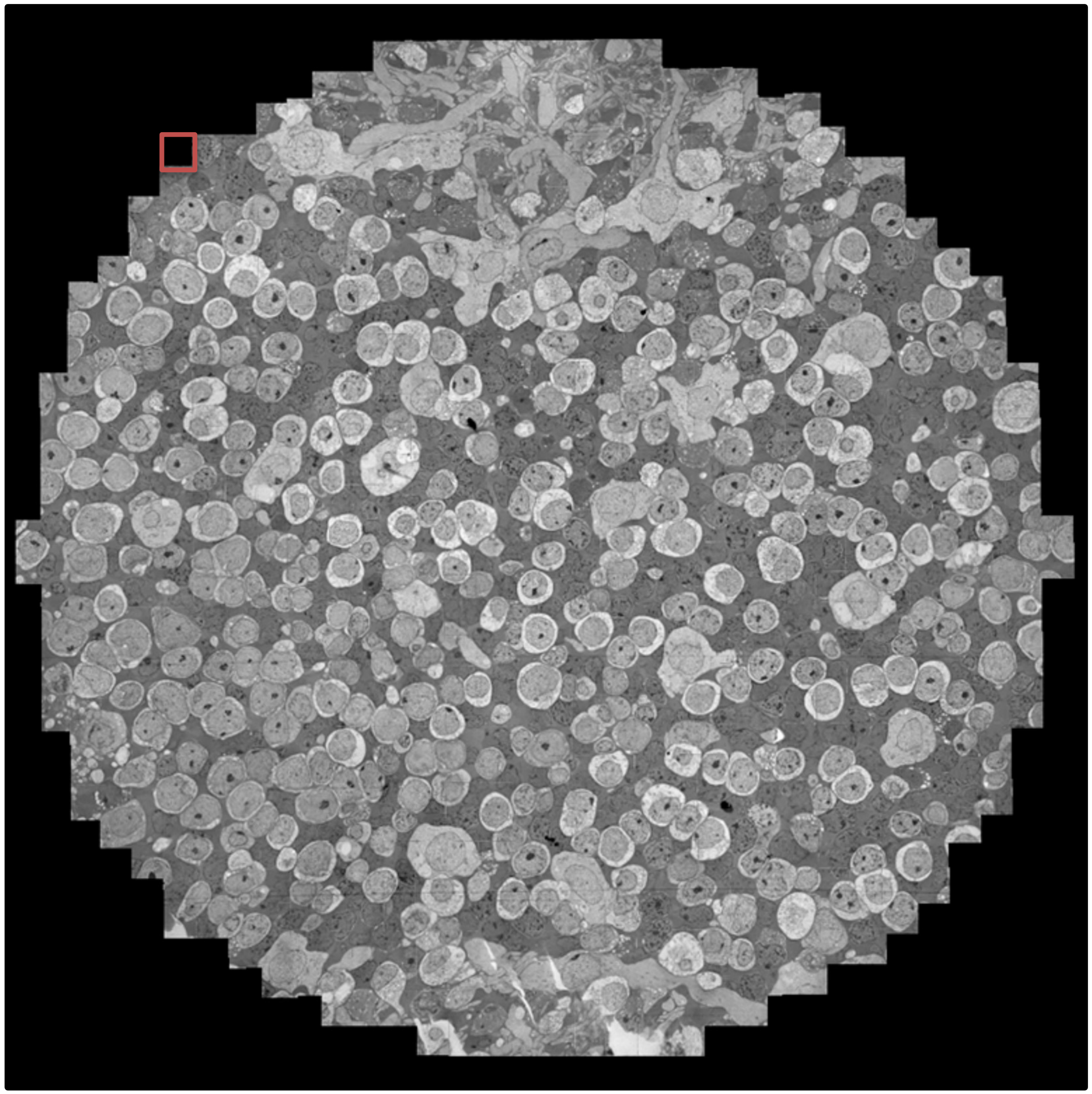

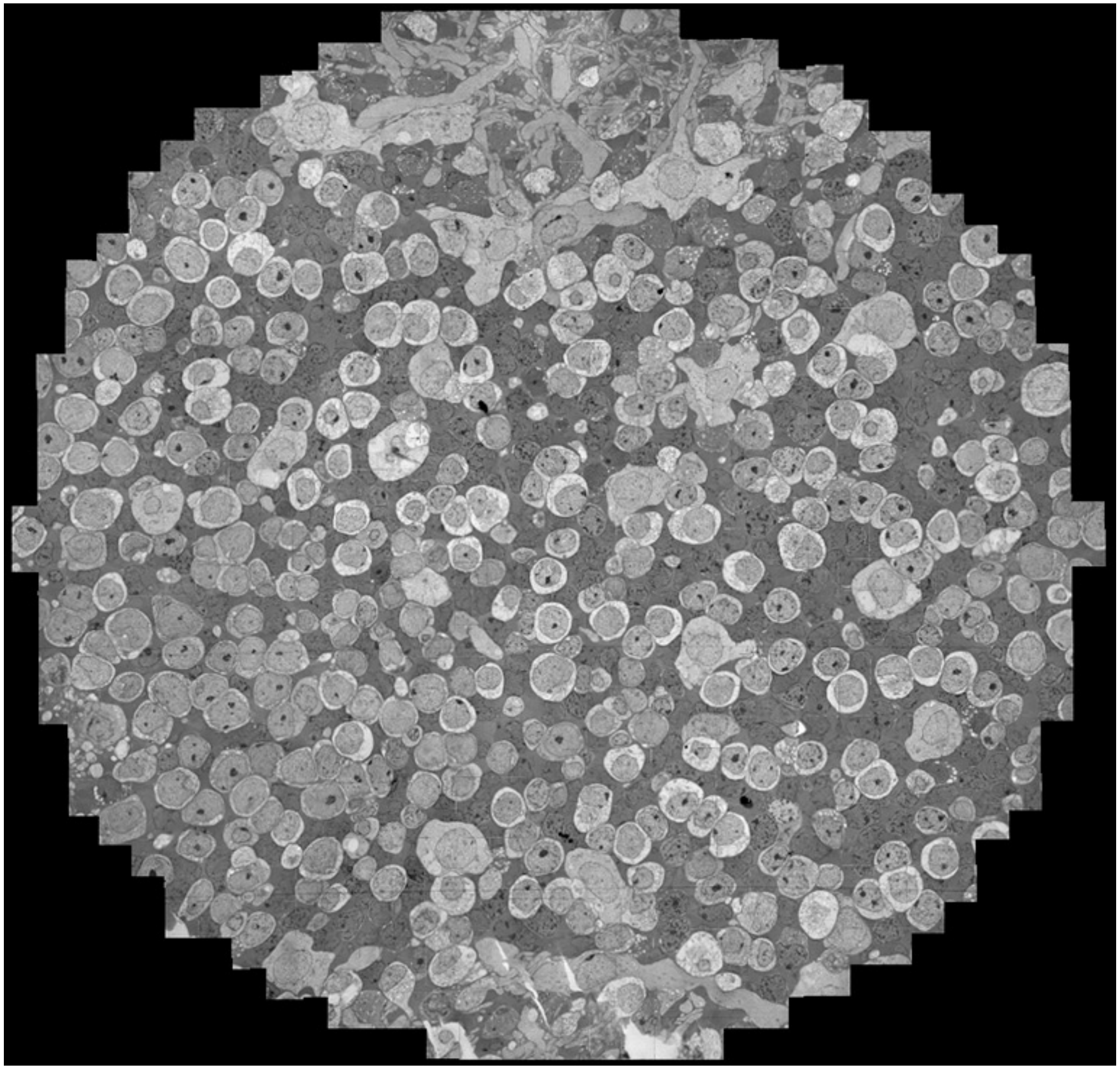

341 Sections
90nm thick sections
~32GB/Section
~1000 tiles/section
4096x4096 pixels/tile
2.18 nm/Pixel
16.5 TB after processing

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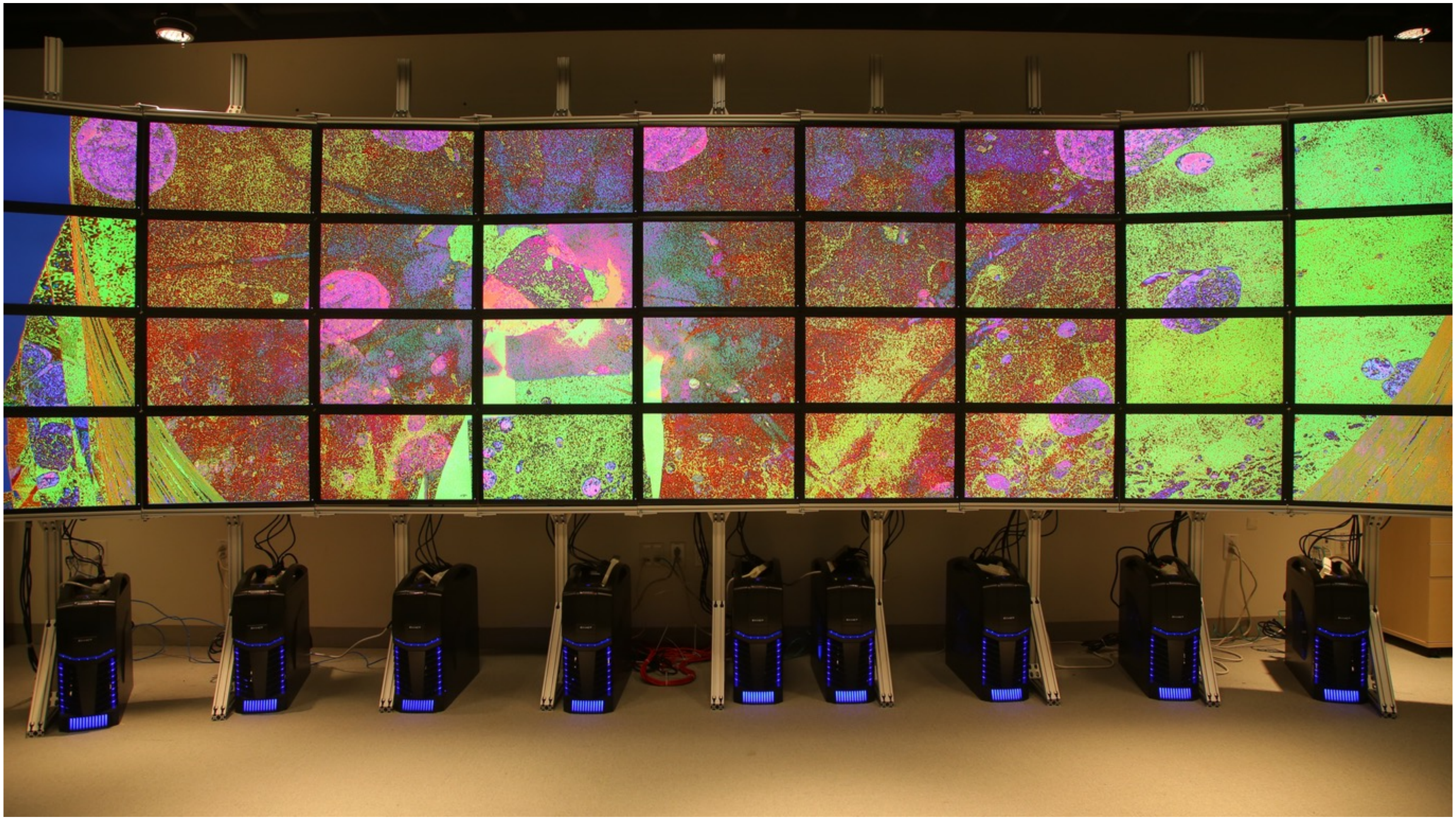
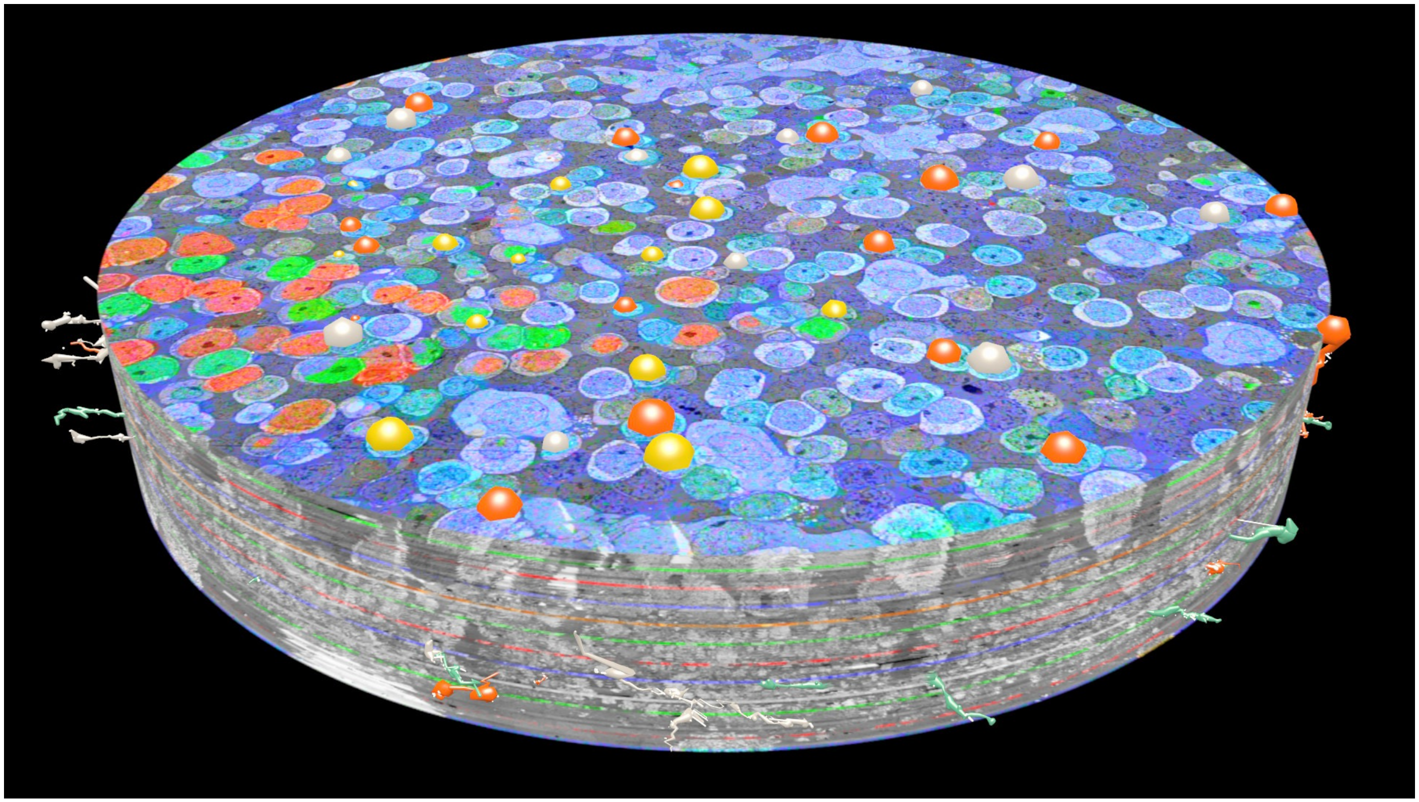


Connectome



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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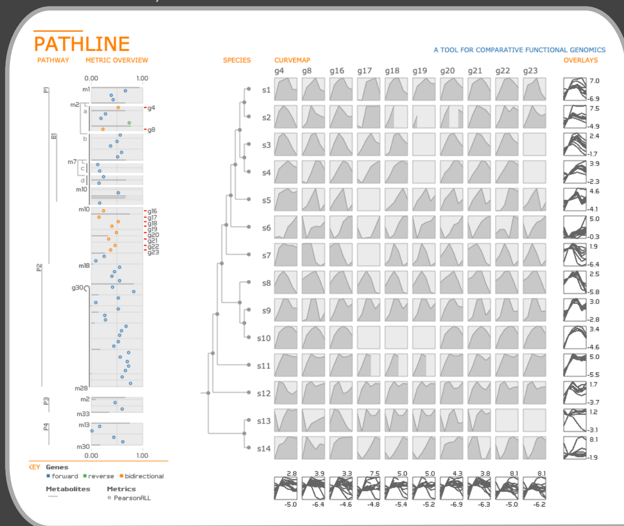
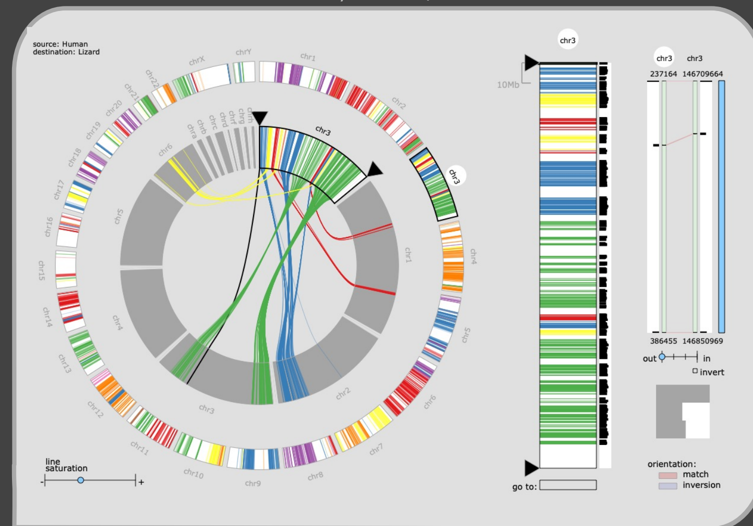
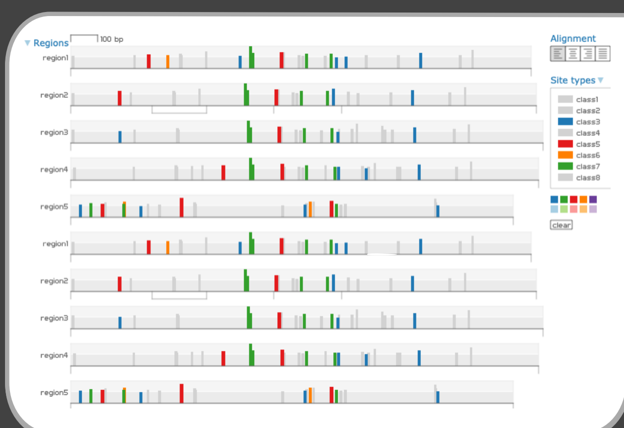
M. Meyer et al., EuroVis 2010. **Pathline**

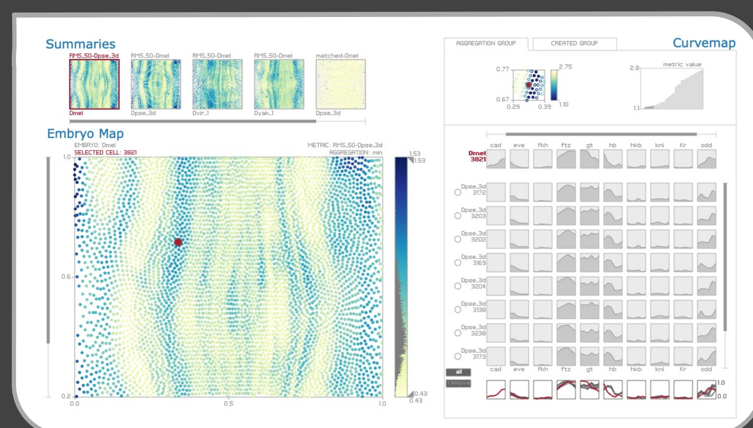


MizBee *M. Meyer et al., InfoVis 2009.*





InSite



MulteeSum *M. Meyer et al., InfoVis 2010.*

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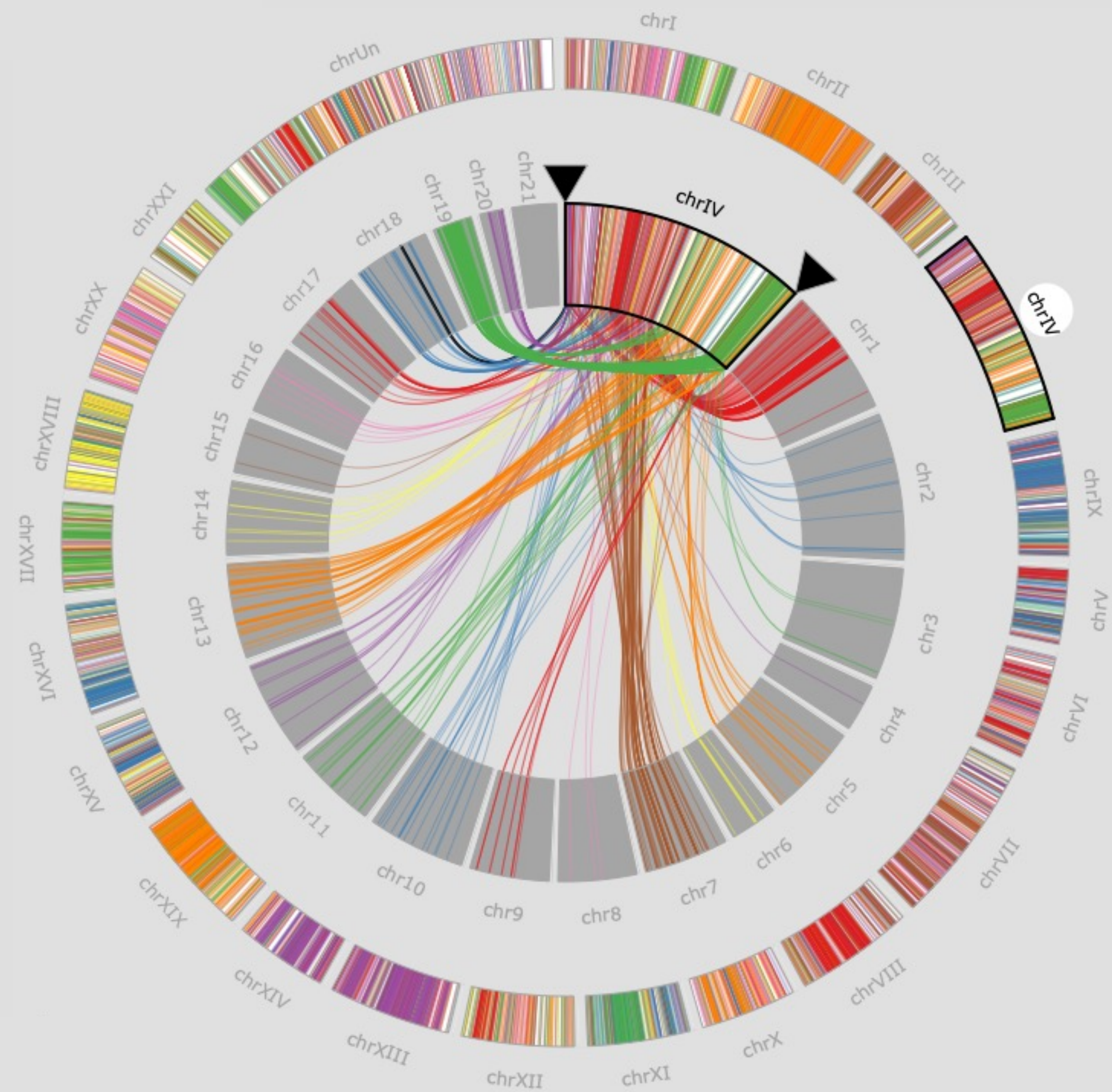

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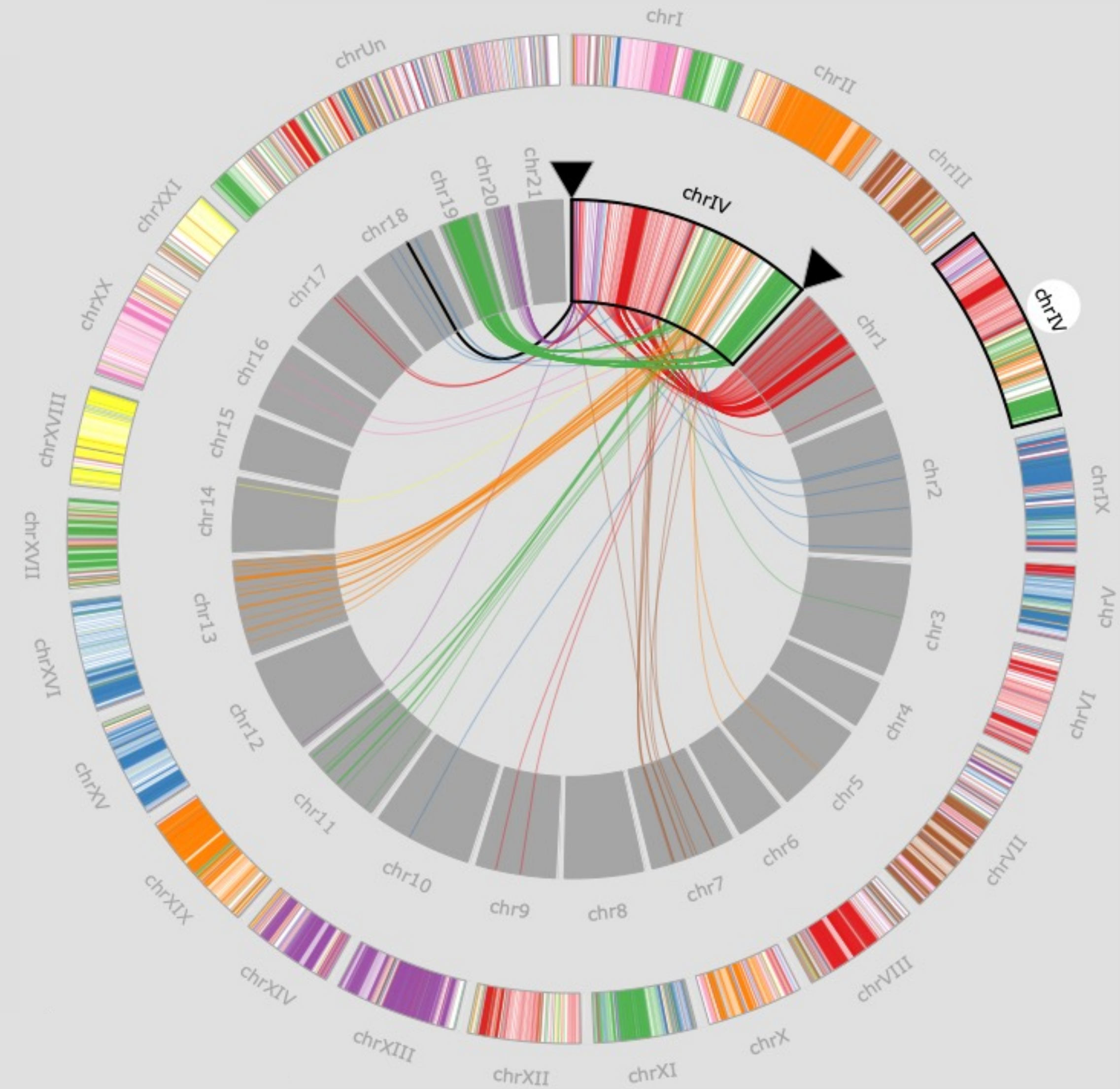

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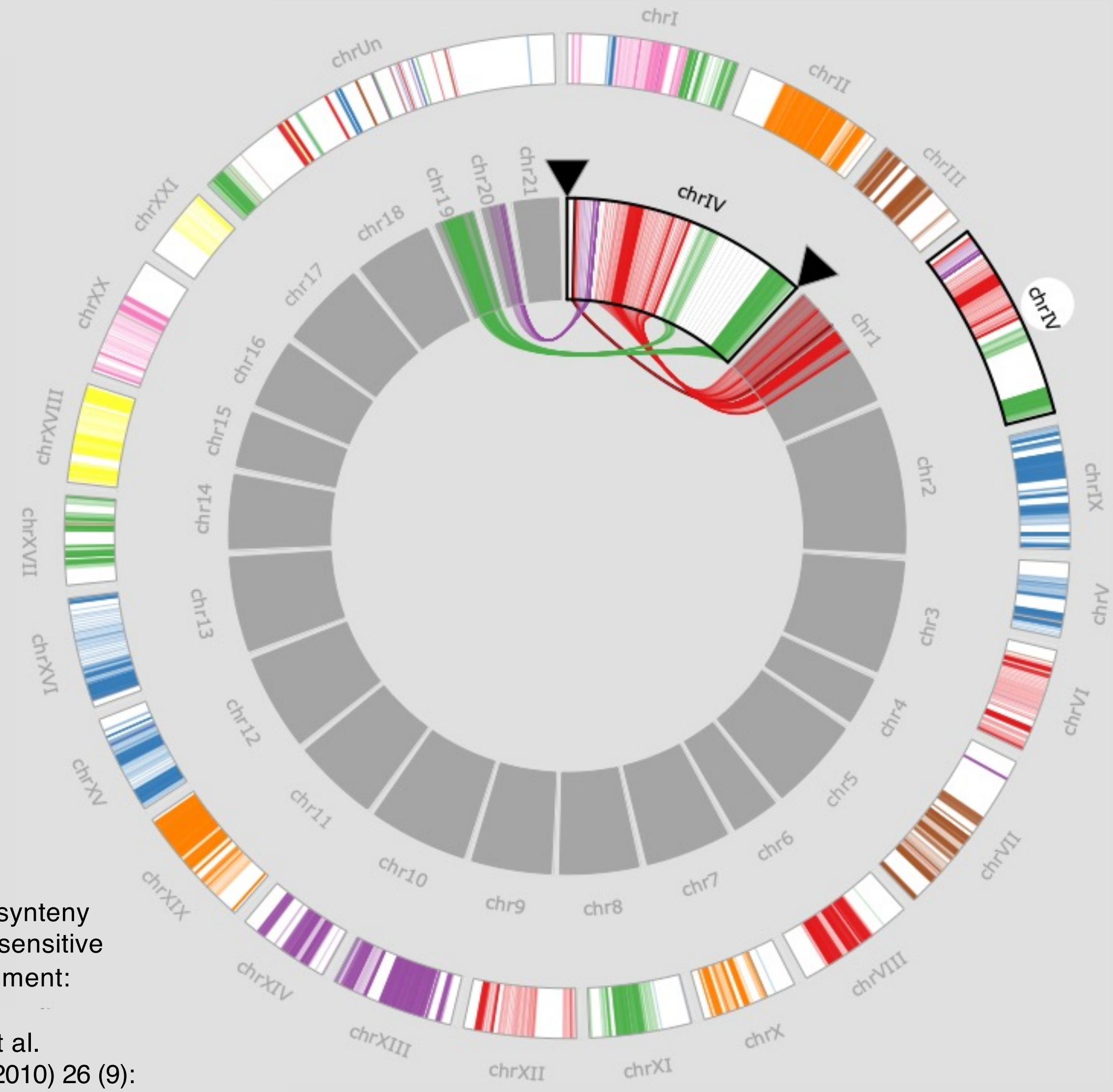

Genome-wide synteny through highly sensitive sequence alignment: Satsuma

M. Grabherr, et al. Bioinformatics (2010) 26 (9): 1145-1151.

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Visualization of Biological Data

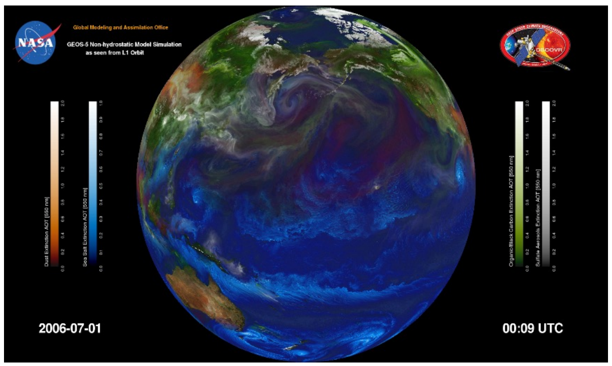
MizBee

Browser that enables analysis of comparative genomics data through visualization across multiple scales.

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*

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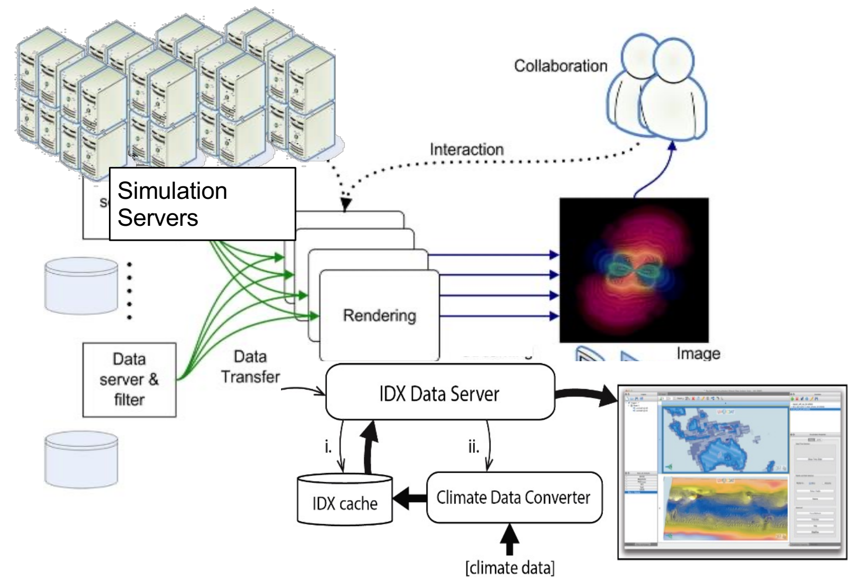
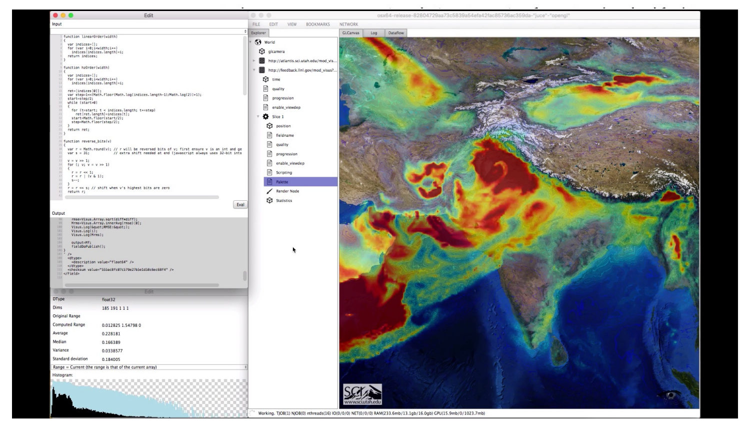
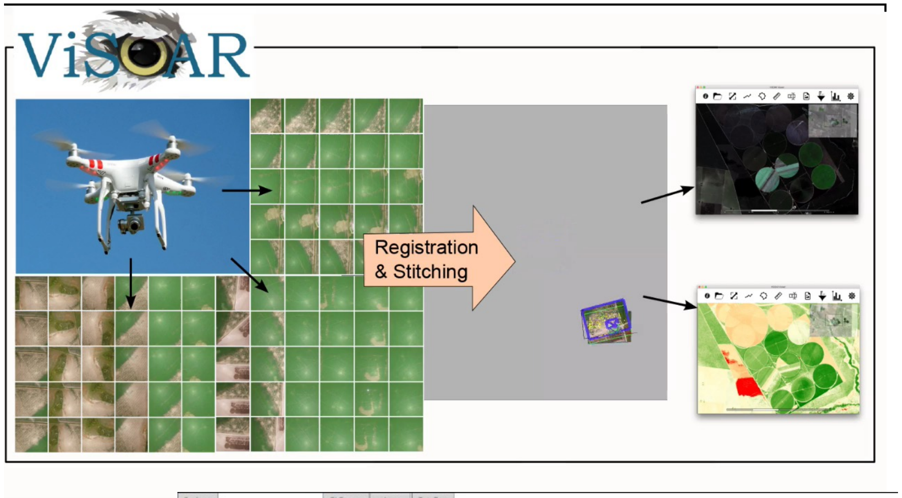
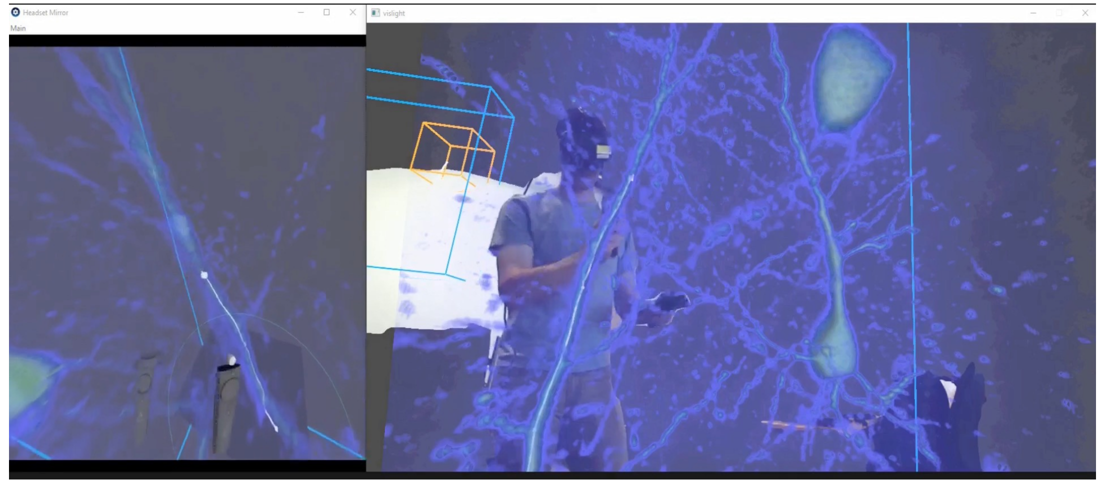
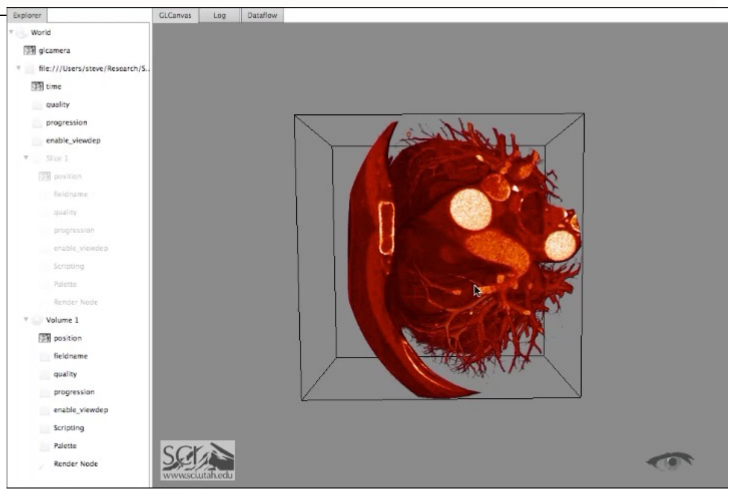
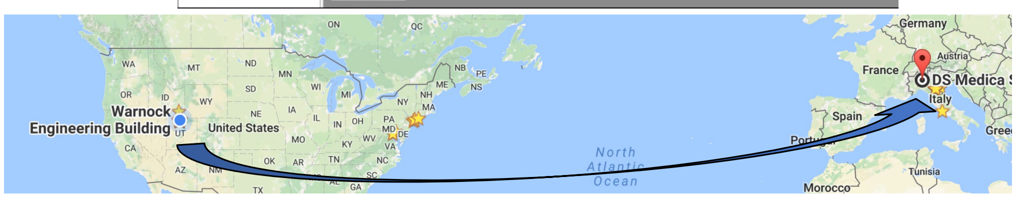




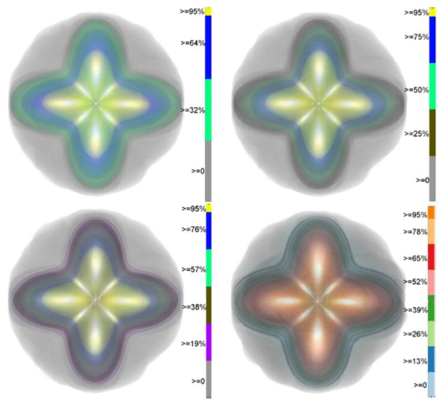

ViSOAR
Registration
& Stitching



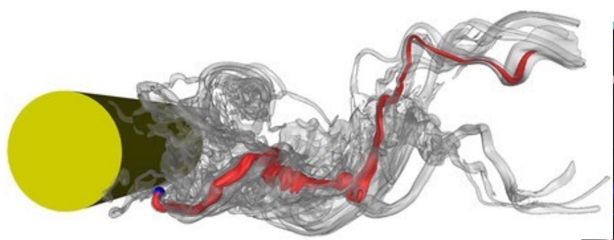

Explorer
GLCanvas
Log
Dataflow
World
glcamera
time
quality
progression
enable_viewdep
Volume 1
position
fieldname
quality
progression
enable_viewdep
Scripting
Palette
Render Node

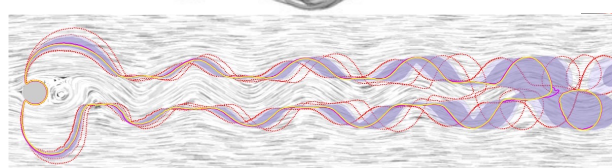

Warnock
Engineering Building
United States
North
Atlantic
Ocean
France
Spain
Italy
Germany
Austria
Tunisia
Morocco

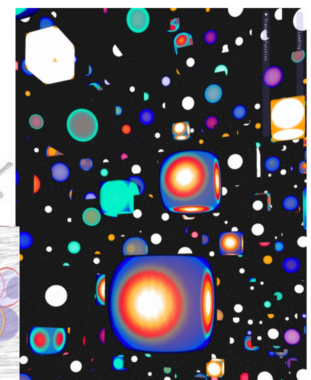
Uncertainty Visualization

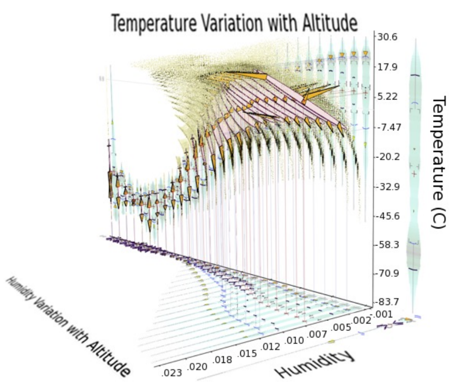


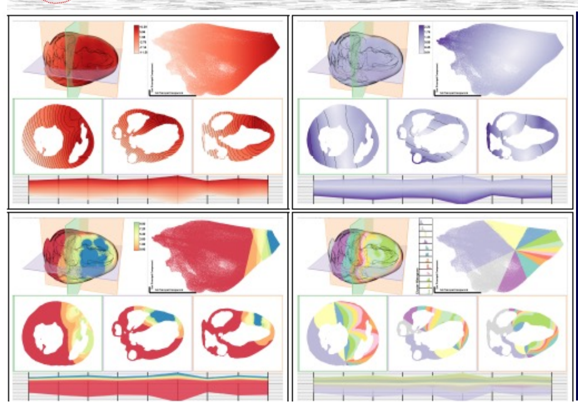
When is the last time you've seen an error bar on an isosurface?

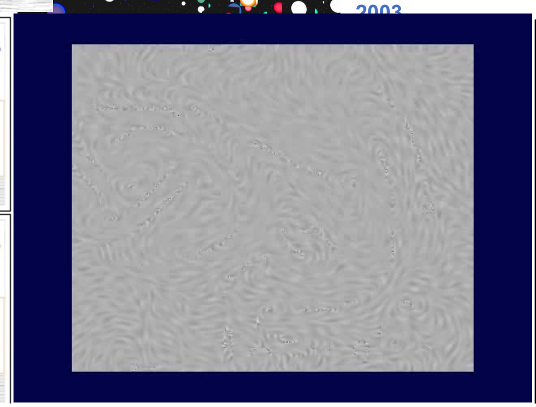


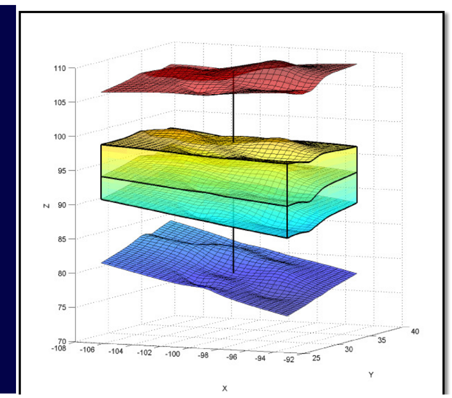












G.P. Bonneau, H.C. Hege, C.R. Johnson, M.M. Oliveira, K. Potter, P. Rheingans, T. Schultz. "Overview and State-of-the-Art of Uncertainty Visualization," In *Scientific Visualization: Uncertainty, Multifield, Biomedical, and Scalable Visualization*, Edited by M. Chen and H. Hagen and C.D. Hansen and C.R. 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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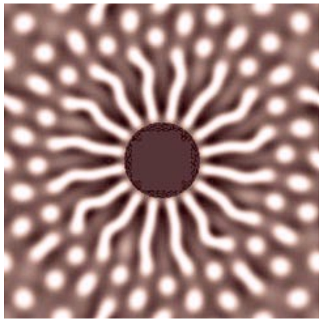
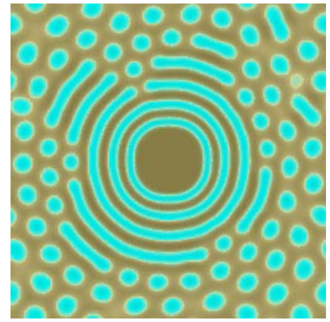
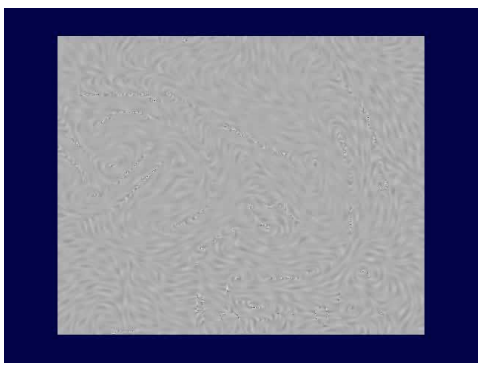
Alan Turing on Finding Patterns

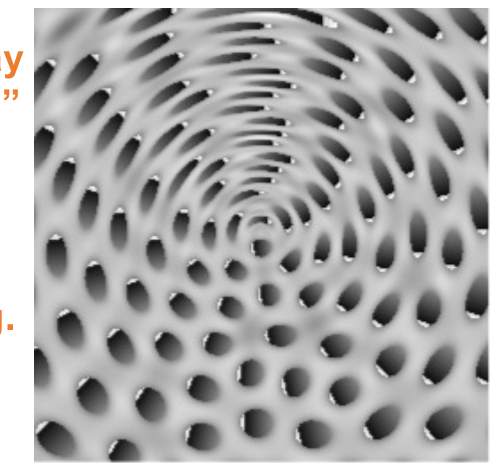


Alan Turning, The Chemical Basis of Morphogenesis,
Philosophical Transactions of the Royal Society of London , 1952





A.R. Sanderson, C.R. Johnson, R.M. Kirby. "Display of Vector Fields Using a Reaction Diffusion Model," In *Proceeding of IEEE Visualization 2004*, pp. 115--122. 2004



A.R. Sanderson, R.M. Kirby, C.R. Johnson, L. Yang. "Advanced Reaction-Diffusion Models for Texture Synthesis," In *Journal of Graphics Tools*, Vol. 11, No. 3, pp. 47--71. 2006.

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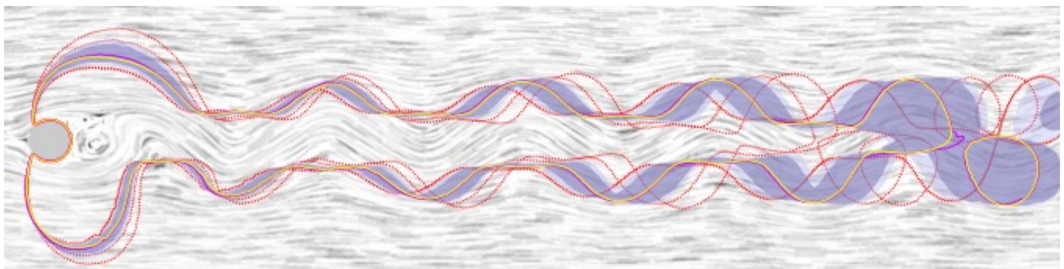
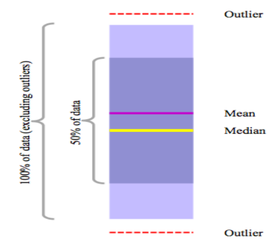
Contour Box Plots

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

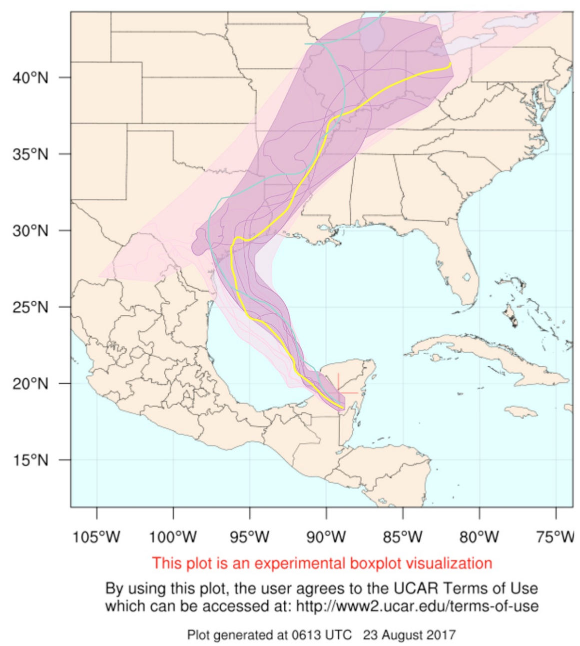


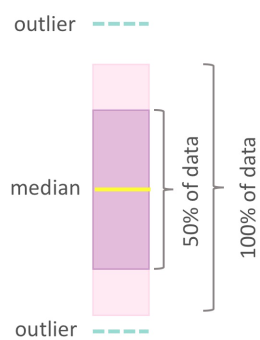


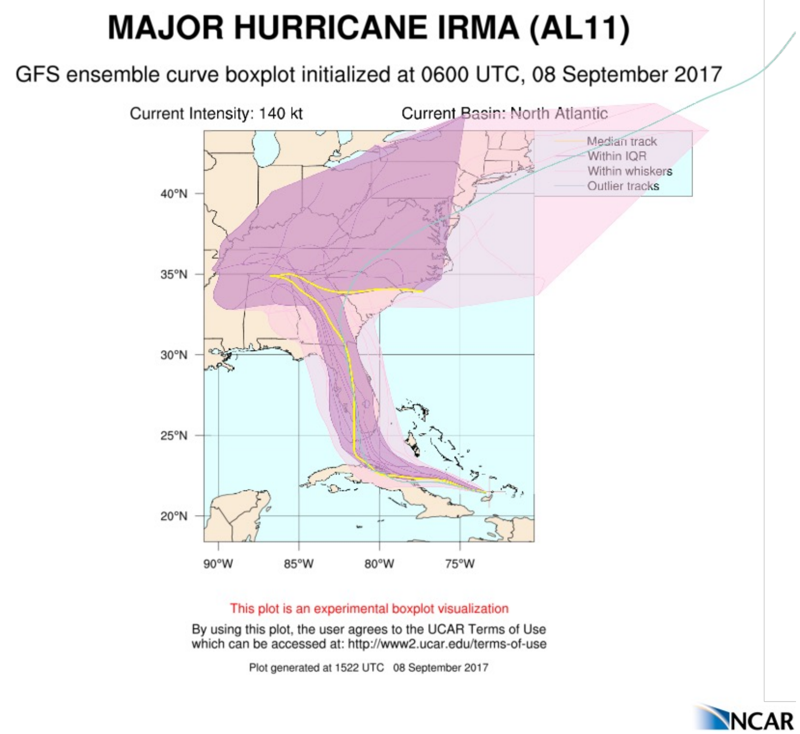
Whitaker, Mirzargar, Kirby, *IEEE Transactions on Visualization and Computer Graphics*, Vol. 19, No. 12, pp. 2713--2722, 2013.

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.

Ensemble Curved Boxplot







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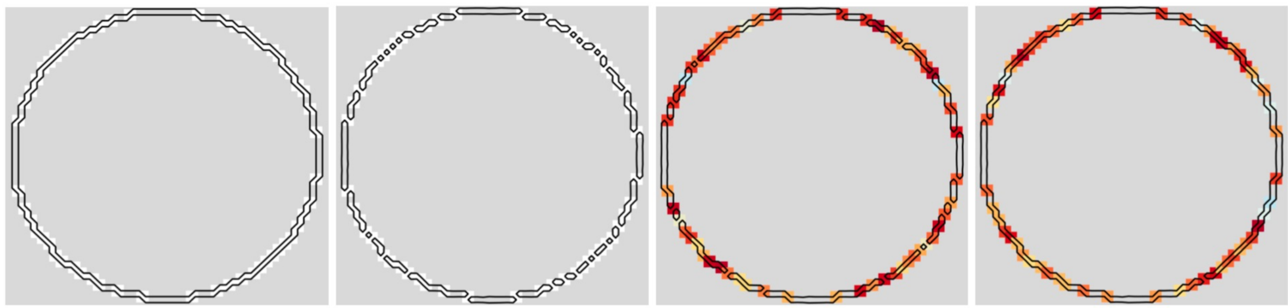
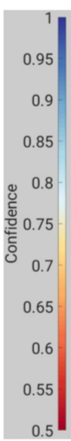
Probabilistic Asymptotic Decider for Topological Ambiguity Resolution in Level-Set Extraction for Uncertain 2D Data

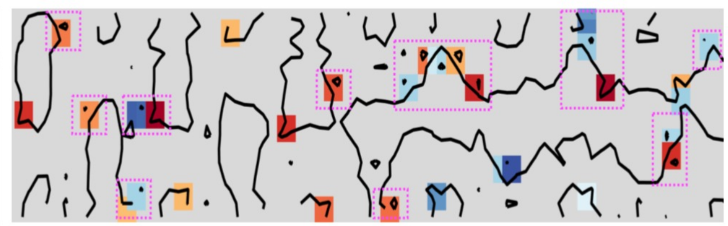
Tushar Athawale and Chris R. Johnson



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

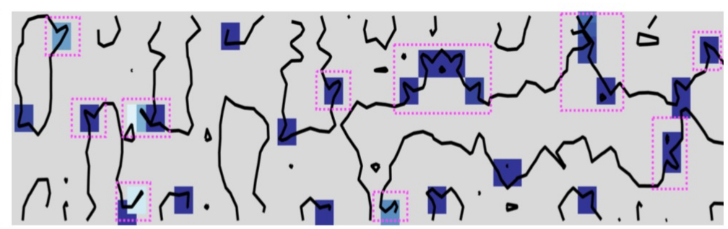


I. The probabilistic midpoint decider



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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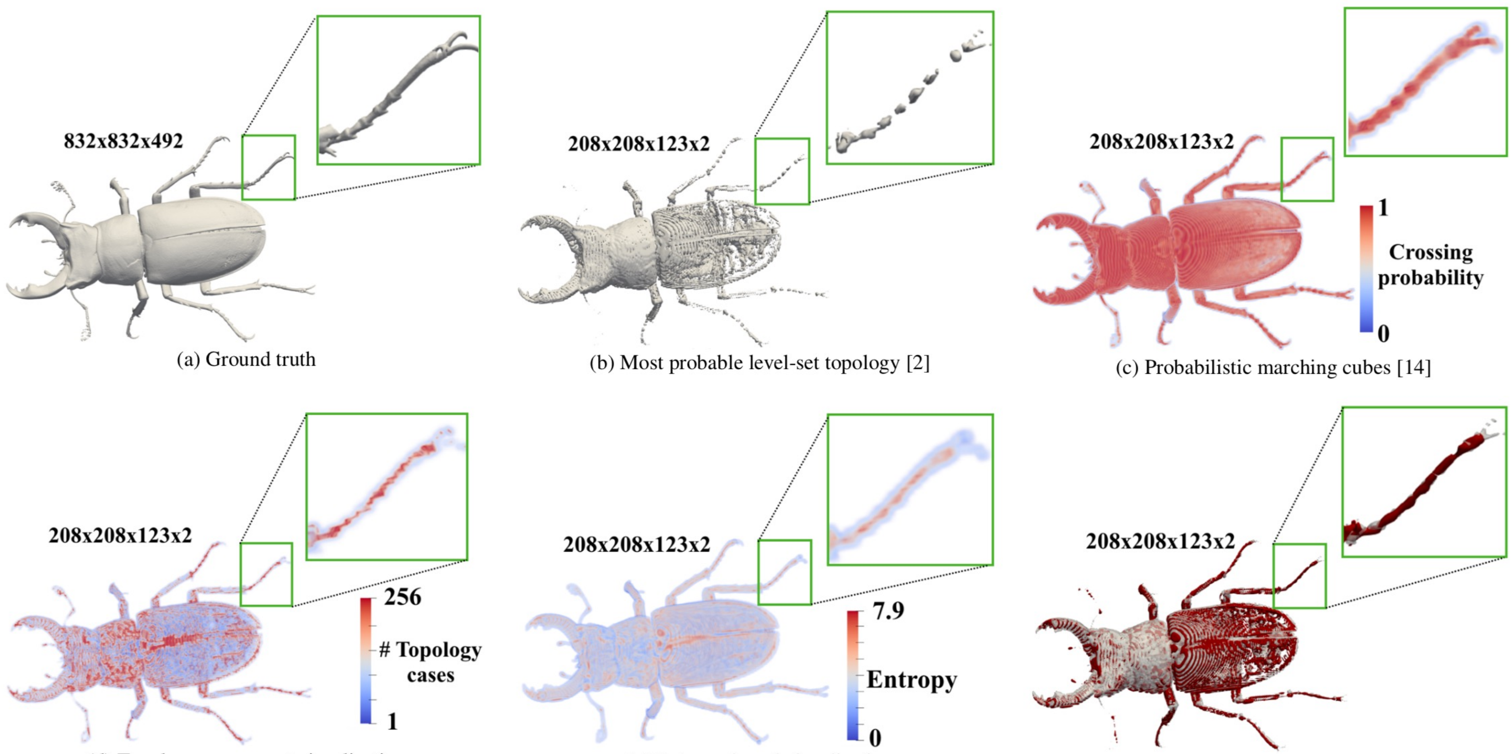
Uncertainty Visualization of the Marching Squares and Marching Cubes Topology Cases - VIS 2021



(a) Ground truth (b) Most probable level-set topology [2] (c) Probabilistic marching cubes [14]

(d) Topology case count visualization (e) Entropy-based visualization (f) Entropy level-set (red)

Figure 5: Uncertainty visualizations for the stag beetle [21] hixel dataset at $k = 900$. The noise in the data results in breaking of the beetle leg in image (b). In probabilistic marching cubes, it is difficult to distinguish between the regions of high and topological uncertainty, which is easier using our visualizations in images (d-f). The relatively high sensitivity of the beetle leg topology to noise is detected in images (d-f) by the red regions. In image (f), the most probable level-set (gray) is overlaid with the entropy volume level-set (red) for entropy isovalue 5.

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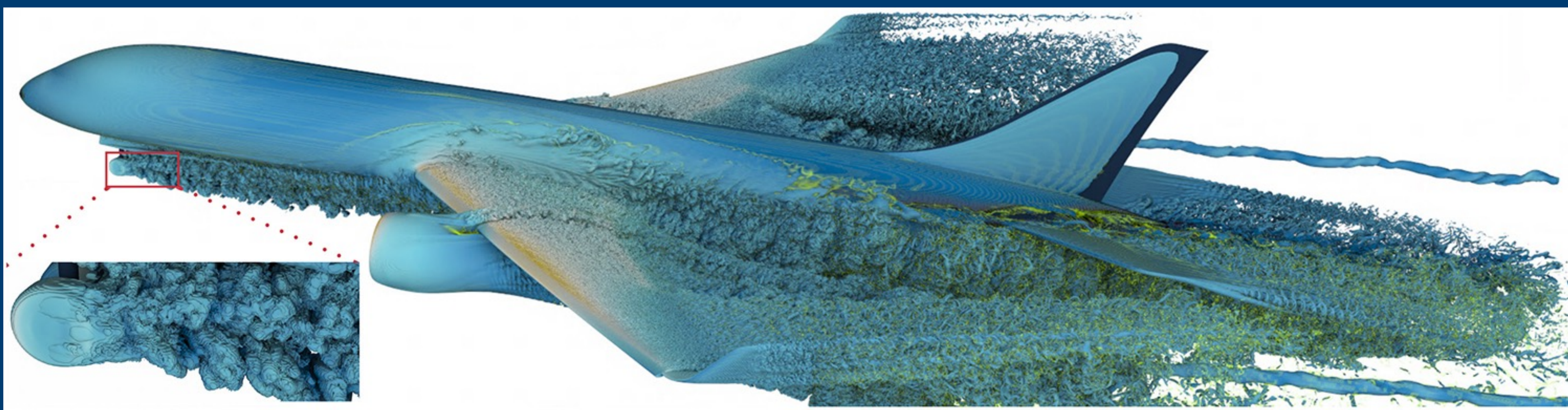
CPU Ray Tracing of Tree-Based Adaptive Mesh Refinement Data

• An efficient high-fidelity visualization solution for both AMR and other multiresolution grid datasets on multicore CPUs, supporting empty space skipping, adaptive sampling and isosurfacing.

• Integration of our method into the OSPRay ray tracing library and open-source release to make it widely available to domain scientists



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F. Wang, N. Marshak, W. Usher, C. Burstedde, A. Knoll, T. Heister, C. R. Johnson. **"CPU Ray Tracing of Tree-Based Adaptive Mesh Refinement Data,"** In *Eurographics Conference on Visualization (EuroVis) 2020*, Vol. 39, No. 3, 2020.

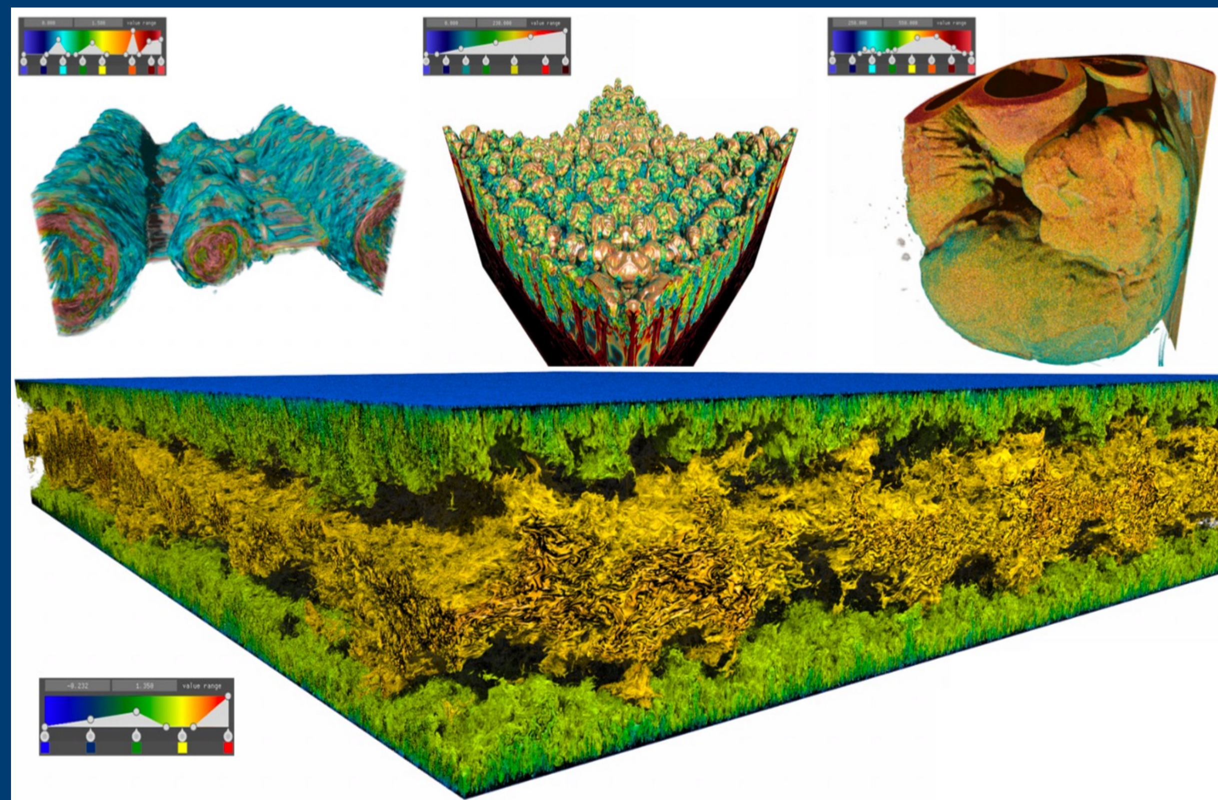
Bricktree for Large-scale Volumetric Data Visualization

- Interactive visualization solution for large-scale volumes in OSPRay

+ Quickly loads progressively higher resolutions of data, reducing user wait times

- Bricktree – a low-overhead hierarchical structure allows for encoding a large volume into multi-resolution representation

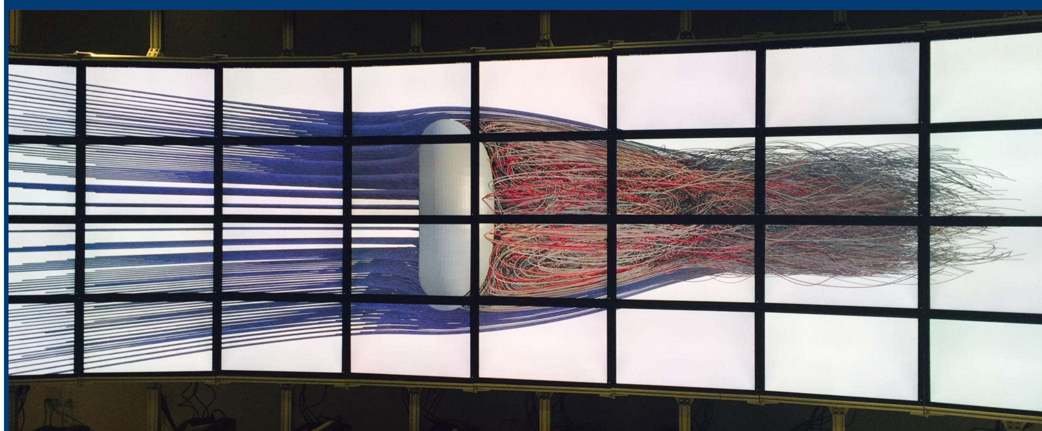
- Rendered via OSPRay module



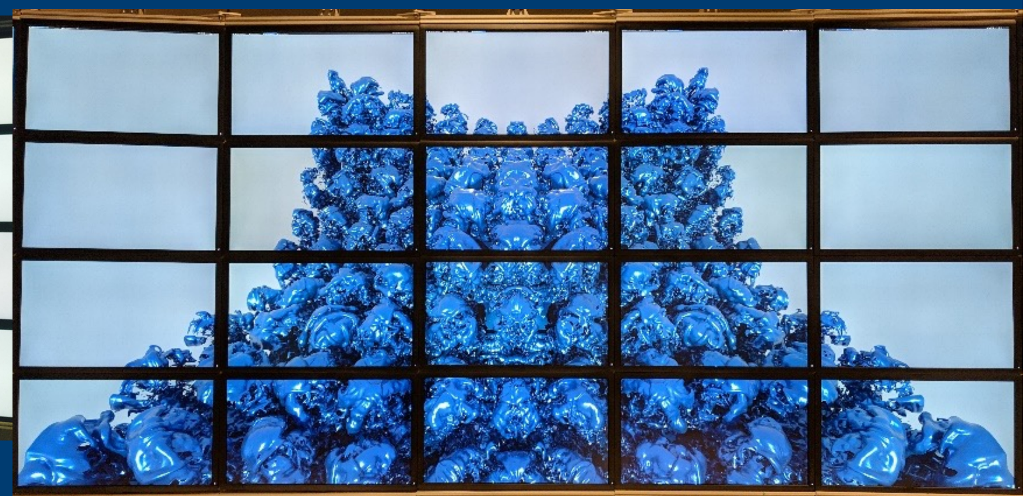
F. Wang, I. Wald, and C.R. Johnson. Interactive Rendering of Large-Scale Volumes on Multi-Core CPUs *IEEE Symposium on Large Data Analysis and Visualization 2019*, pp. 27-36, 2019.

Display Wall Rendering with OSPRay

+ Software infrastructure that allows parallel renderers (OSPRay) to render to large-tiled display clusters.
+ Decouples the rendering cluster and display cluster
+ Lightweight, inexpensive and easy to deploy options via Intel NUC + remote rendering cluster



Streamlines computed on flow past a torus



300M triangle isosurface on the Richtmeyer Meshkov

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M. Han, I. Wald, W. Usher, N. Morrical, A. Knoll, V. Pascucci, and C.R. Johnson. A Virtual Frame Buffer Abstraction for Parallel Rendering of Large Tiled Display Walls. *IEEE Visualization 2020*,

Interactive Streamline Exploration and Manipulation using Deformation

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Han-Wei Shen[1], Chris R. Johnson[2], Pak Chung Wong[3]
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