OAK RIDGE National Laboratory

Statistical Analysis for Uncertainty Quantification and Visualization of Scientific Data

Tushar M. Athawale

Dagstuhl Seminar on Visualization and Decision Making Design Under Uncertainty

ORNL is managed by UT-Battelle, LLC for the US Department of Energy

U.S. DEPARTMENT OF ENERGY

(Collaboration with the SCI Institute at the University of Utah)

SCI www.sci.utah.edu

Background

University of Florida (2010 – 2015)
Thesis: Uncertainty quantification for isosurface visualization

MathWorks (2015 – 2016)

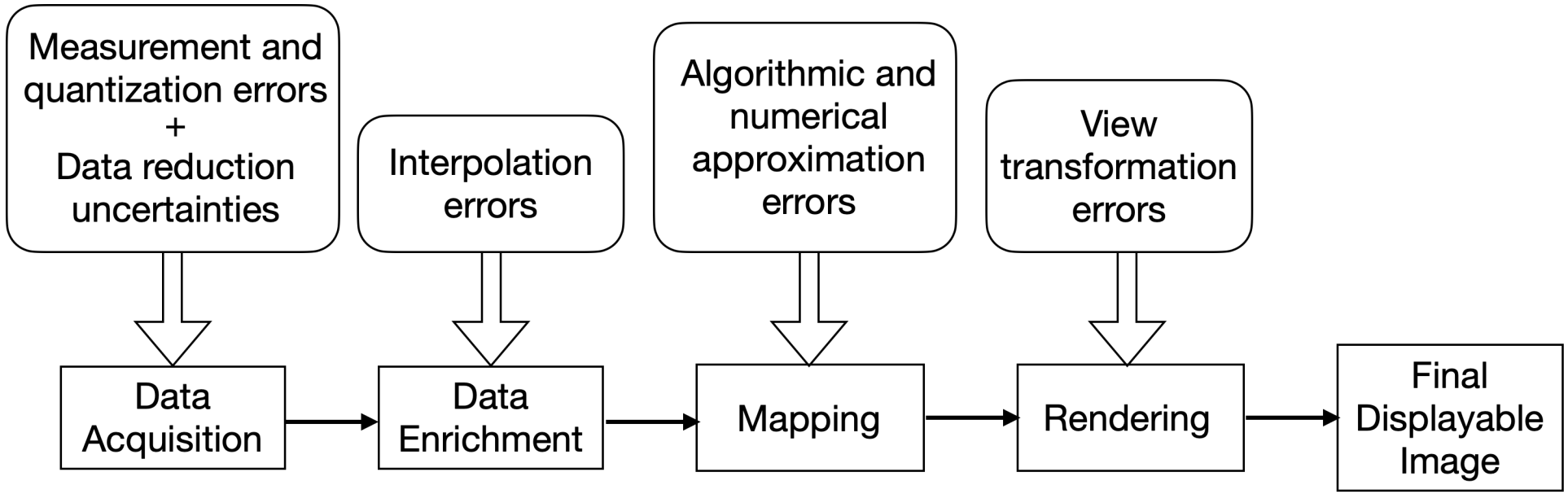
SCI Institute, University of Utah
(2016 – 2021)

Oak Ridge National Laboratory
(2021-Present)

Uncertainty Visualization: Top Research Challenge

[A. T. Pang, C. M. Wittenbrink, and S. K. Lodha, “Approaches to Uncertainty Visualization”, 1997]
[C. R. Johnson and A. R. Sanderson, “A Next Step: Visualizing Errors and Uncertainty”, 2004]

Challenge: Not easy to quantify and convey uncertainties propagated through HPC and visualization pipelines!

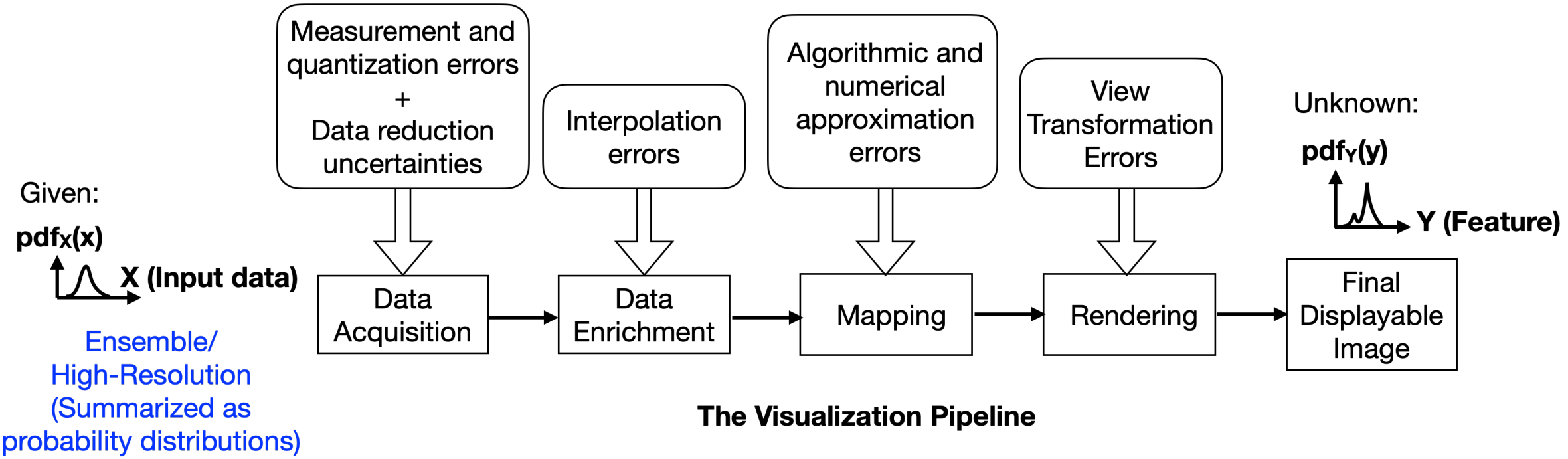


The Visualization Pipeline

[K. Brodlie, R. A. Osorio, and A. Lopes, “A Review of Uncertainty in Data Visualization”, 2012]
[A. Kamal et al., “Recent Advances and Challenges in Uncertainty Visualization”, 2021]

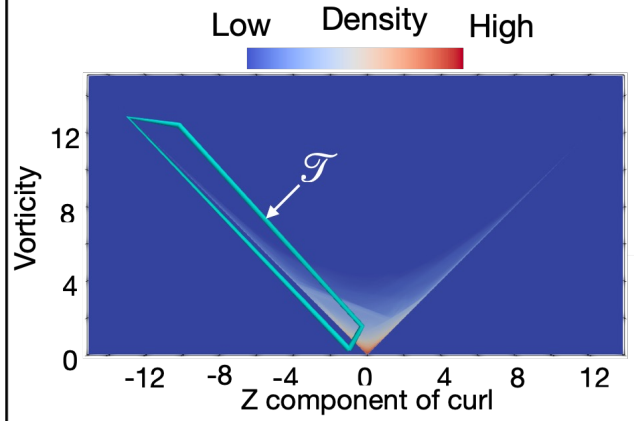
Our Approach to Uncertainty Quantification

Monte Carlo (easy but expensive) vs. Analytical (difficult but fast)

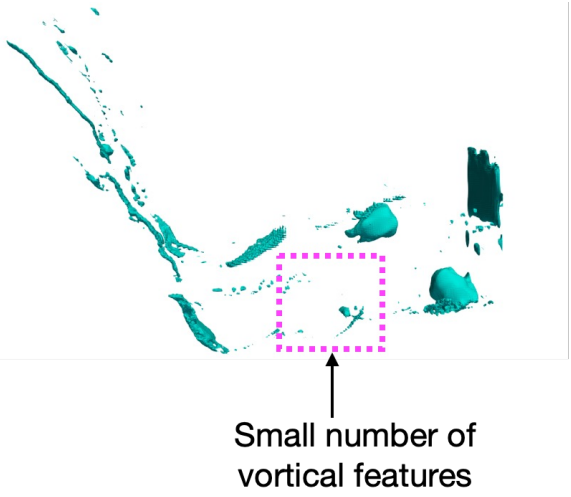


The Visualization Pipeline

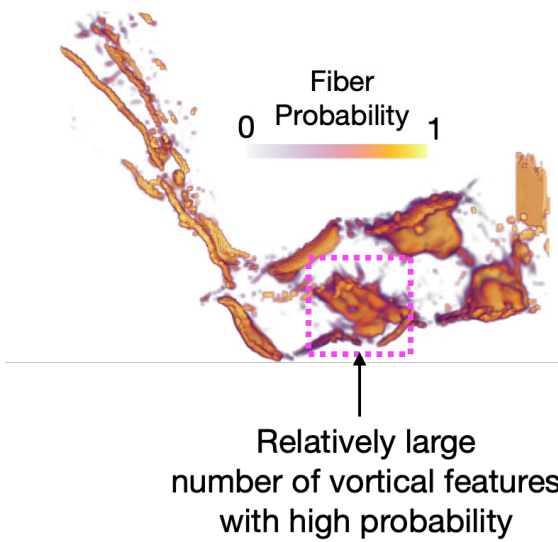
Uncertainty Analysis for Scientific Visualization Algorithms



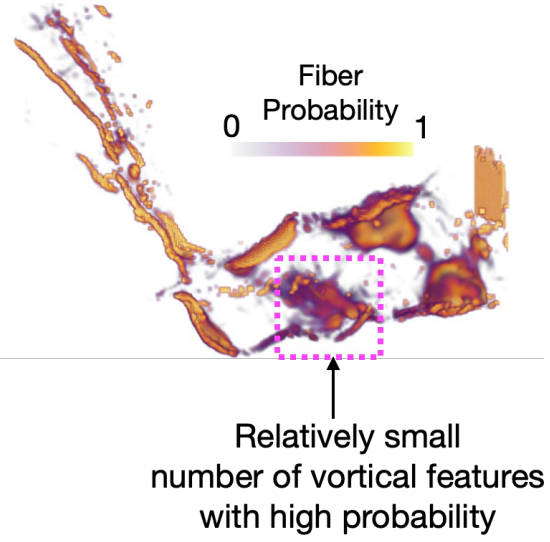
(a) Continuous scatterplot



(b) Mean-field fiber surface

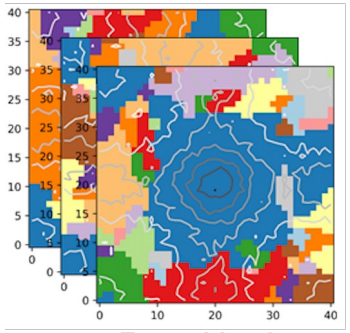


(c) Parametric



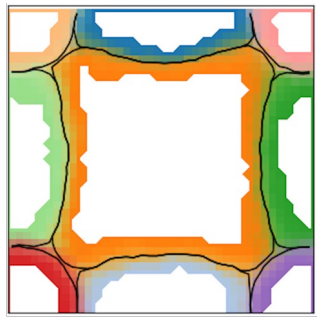
(d) nonparametric

[T. M. Athawale, C. R. Johnson, S. Sane, and D. Pugmire, accepted at IEEE VIS 2022]



Ensemble of Morse Complexes

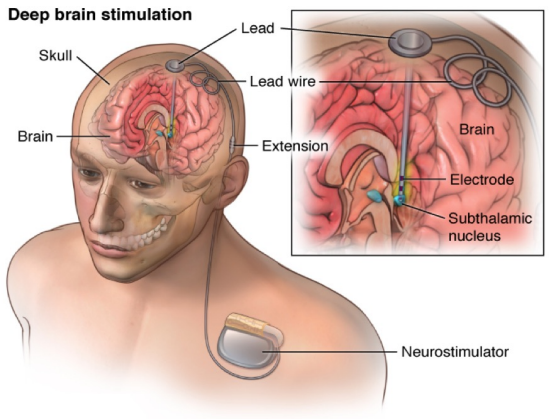
Agreement Regions

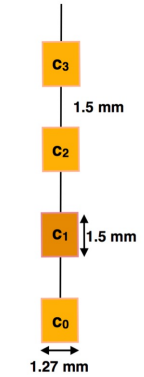


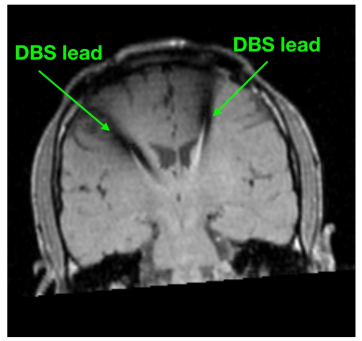
Uncertainty Regions

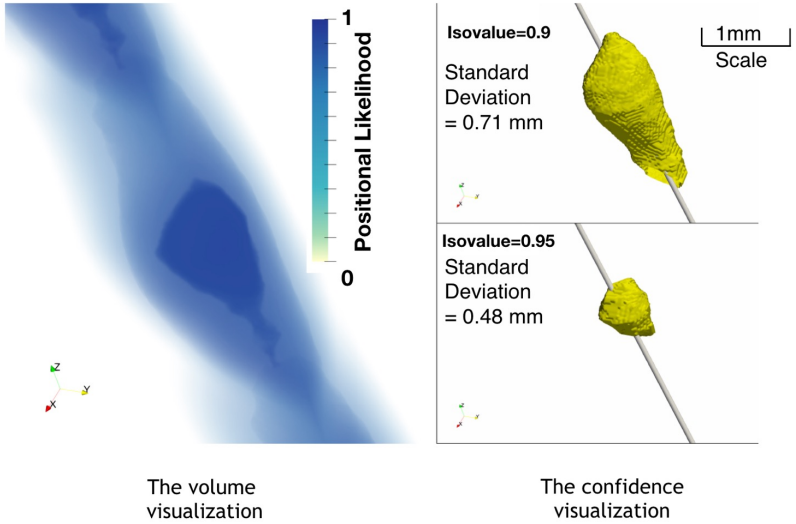
[T. M. Athawale, D. Maljovec, L. Yan, C. R. Johnson, V. Pascucci, and B. Wang, TVCG, 2022]

Uncertainty Visualization for Domain-Specific Data





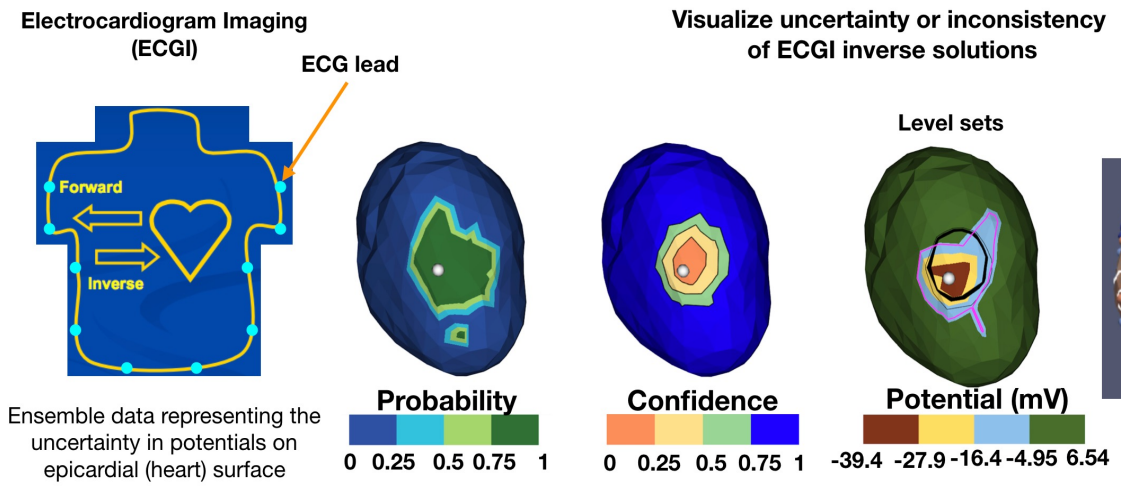




The volume visualization

The confidence visualization

[T. M. Athawale, K. A. Johnson, C. Butson, and C. R. Johnson, 2019]

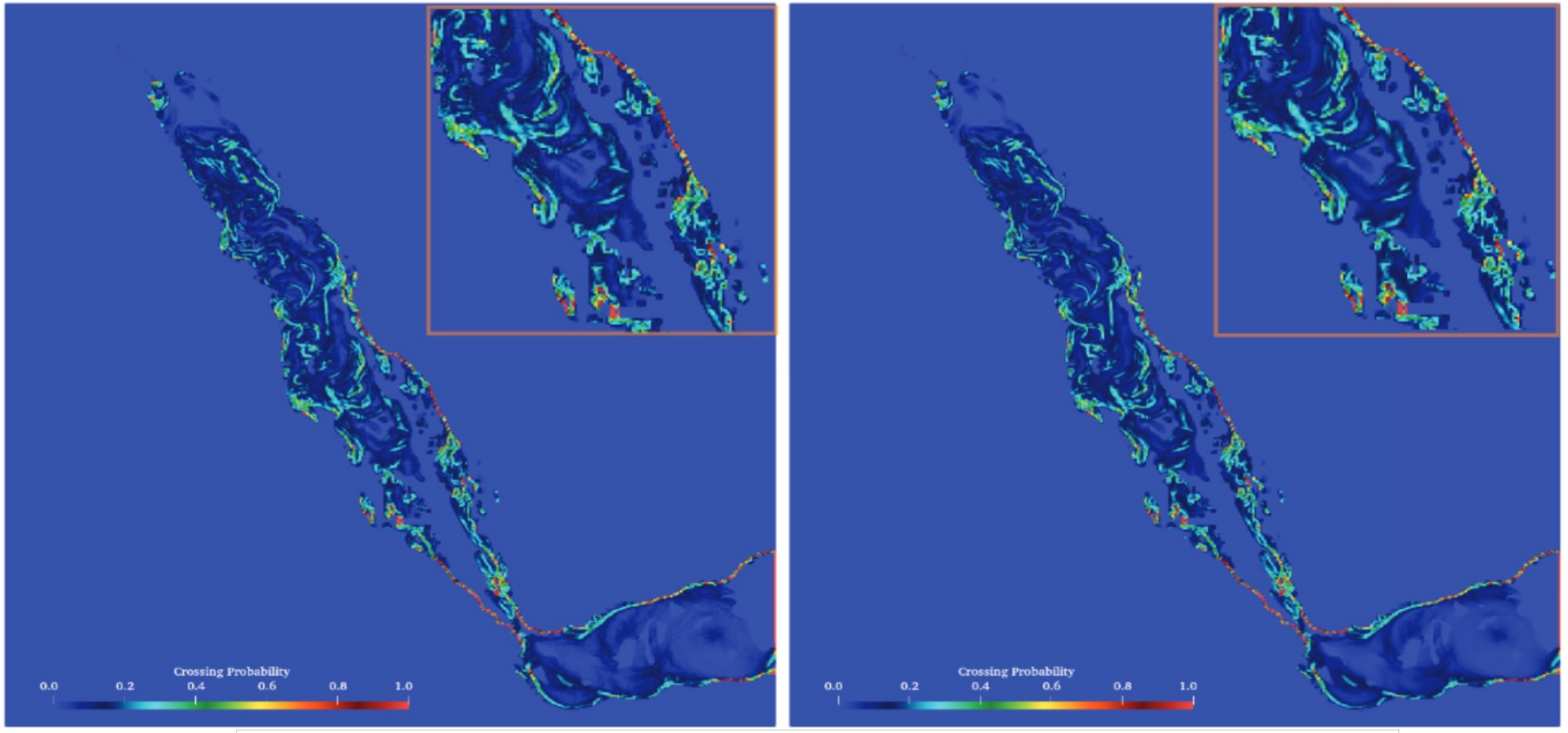


Ensemble data representing the uncertainty in potentials on epicardial (heart) surface

[D. Njeru, T. M. Athawale, J. France, and C. R. Johnson, 2022]

Future Work: Machine Learning for Uncertainty Visualization

Learn uncertainties pertinent to isosurfaces from a bunch of time steps and predict uncertainty for future time steps



Monte Carlo

[K. Pöthkow, B. Weber, and H.-C. Hege, "Probabilistic Marching Cubes", 2011]

Machine Predicted (170X faster)

[M. Han, T. M. Athawale, D. Pugmire, and C. R. Johnson, accepted at IEEE VIS 2022 short papers]

Future Work: Visualization and Decision-Making, A User Study

Collaboration with the University of South Florida, [B. Triana, T. Kotha, T. M. Athawale, D. Pugmire, and P. Rosen]

Which one of the following two noisy images is visually closer to the truth?

Noisy image 1

Truth

Noisy image 2

Open Research Challenges

- Uncertainty quantification for more visualization algorithms and high-dimensional data
- Devising uncertainty-aware decision frameworks to perform optimal algorithmic decisions, reduce uncertainty, and hence enhance quality of visualizations
- Improving interactivity of uncertainty visualization algorithms with machine learning models or GPU acceleration and devising compact data models
- Understanding and managing tradeoffs between computational and memory requirements of uncertainty quantification techniques and timeliness of scientific applications
- Conducting community-wide surveys to assess cognition and decision-making quality

Thanks to Project Collaborators!

Dr. Chris Johnson
(Postdoctoral advisor)

Dr. Alireza Entezari
(PhD advisor)

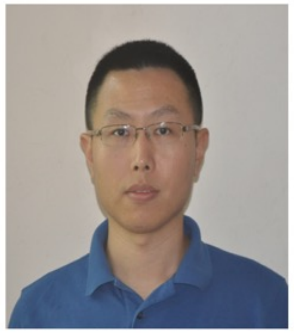
Dr. David Pugmire
(Group leader, Visualization group at ORNL)

Dr. Chris Butson
(DBS project)

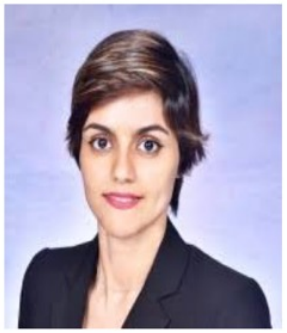
Dr. Bei Wang
(Morse complex project)

Dr. Valerio Pascucci
(Morse complex project)

Dr. Paul Rosen
(Visualization sensitivity analysis project)

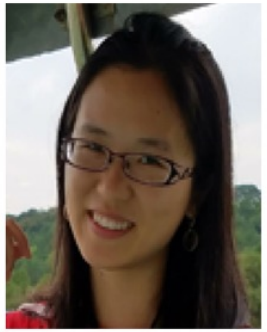


Dr. Bo Ma
(Direct volume rendering project)



Dr. Elham Sakhaee
(Direct volume rendering project)

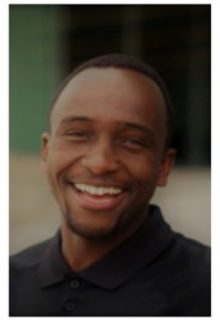
Dr. Kara Johnson
(DBS project)



Dr. Lin Yan
(Morse complex project)

Dr. Dan Maljovec
(Morse complex project)

Dr. Sudhanshu Sane
(Multivariate uncertainty analysis project)



Dennis Njeru
(ECGI project)

Mengjiao Han
(Machine learning for uncertainty vis project)

Thank you!

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