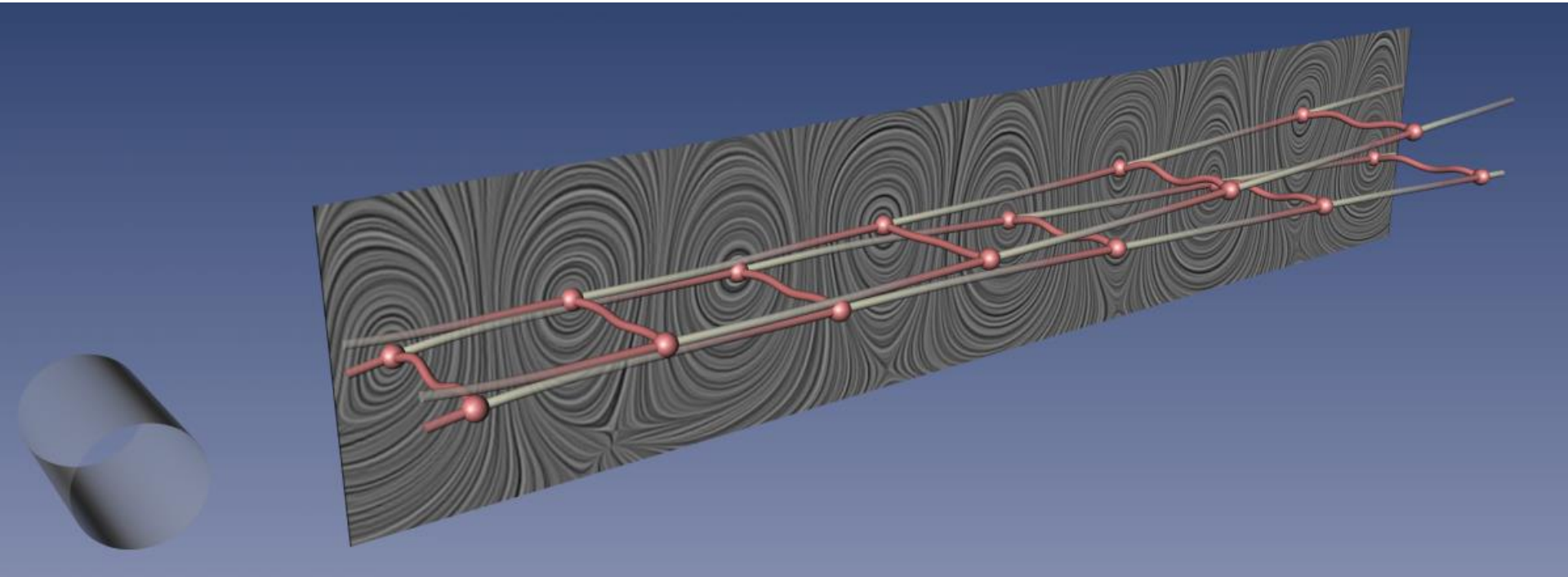


Recent Advancements of Feature-based Flow Visualization and Analysis



Jun Tao, University of Notre Dame, USA

Hanqi Guo, Argonne National Laboratory, USA

Bei Wang, University of Utah, USA

Christoph Garth, University of Kaiserslautern, Germany

Tino Weinkauf, KTH Royal Institute of Technology, Sweden

Milestones in Flight History

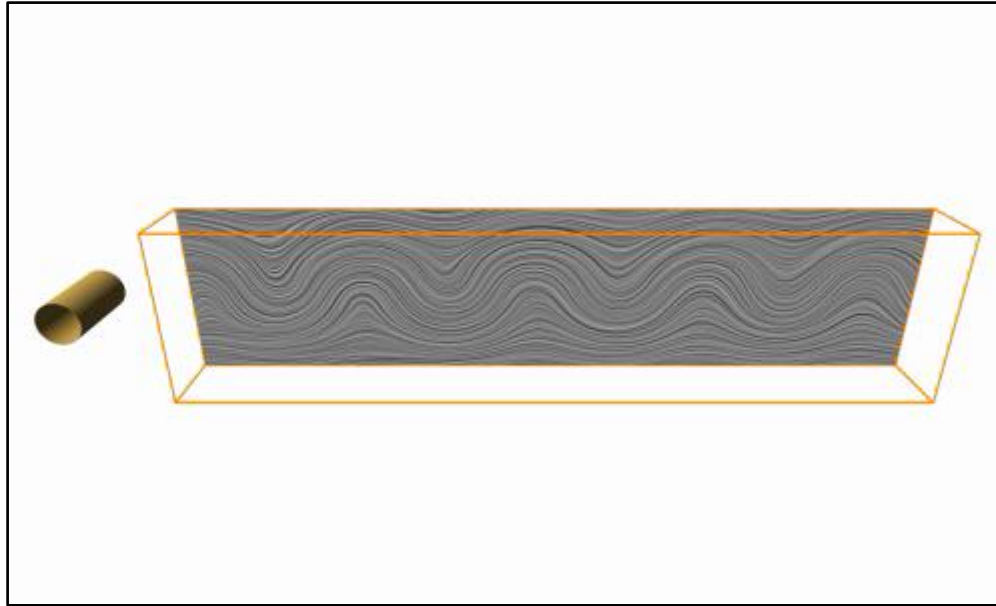
Dryden Flight Research Center



L-1011

Airliner Wing Vortice Tests at Langley

Circa 1970s



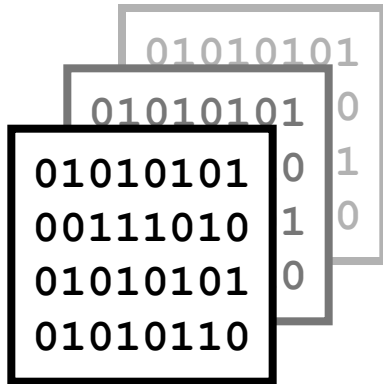
Flow behind a cylinder. Data courtesy of Bernd R. Noack (TU Berlin).

- mimicking real-world visualizations
- enhanced visualizations
- feature-based visualizations

Definition of the term “**Feature**”

- n-dimensional geometrical structure embedded into m-dim. Domain
- yields certain „insight“
- mathematical definition depends on application
- derived quantity revealing interesting structures

Data

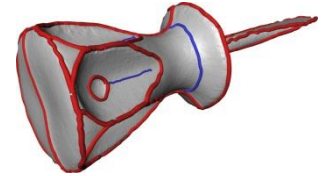


*Large data sets,
multi-run simulations,
parameter space,
3D scanners*

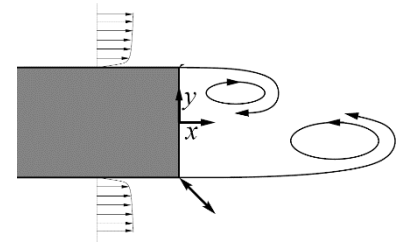
Analysis

*automated
target-oriented
objective*

Benefit



Shape descriptors

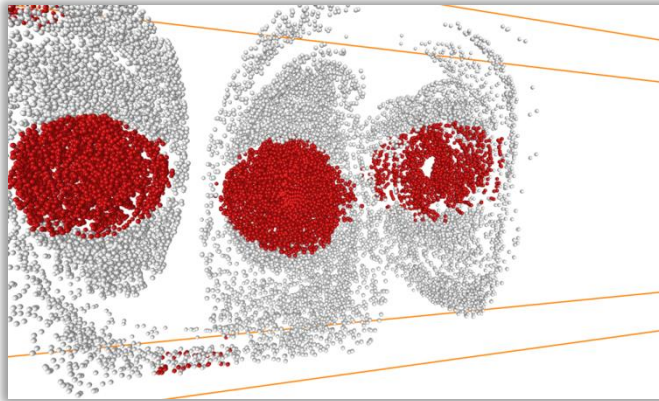


*Conceptual
flow models*

Feature-Based Data Analysis

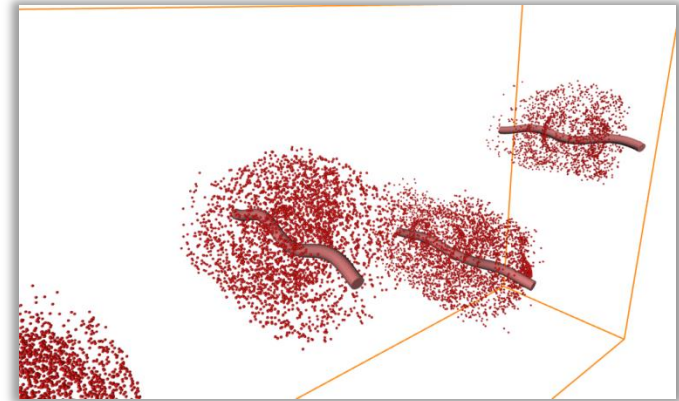
*reduction of information
interactive visualization
faster analysis*

Classic Visualization



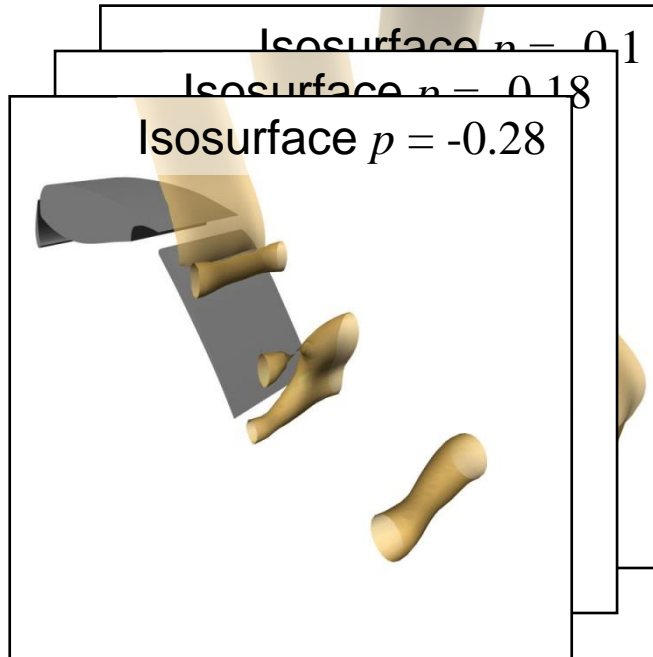
- Showing a feature
 - Human understands what the feature is
- Path? – Velocity? – Life time? – Interdependency? – Importance?
- ➔ Qualitative analysis

Feature-based Visualization



- Having a feature and showing it
 - Human and Computer understand what the feature is
- Path! – Velocity! – Life time! – Interdependency! – Importance!
- ➔ Quantitative analysis (e.g. statistics)
- ➔ Qualitative analysis

Classic Visualization



*This is tedious, repetitive work!
Did I miss something?*

Yes, I get the basic idea.

Feature-based Visualization



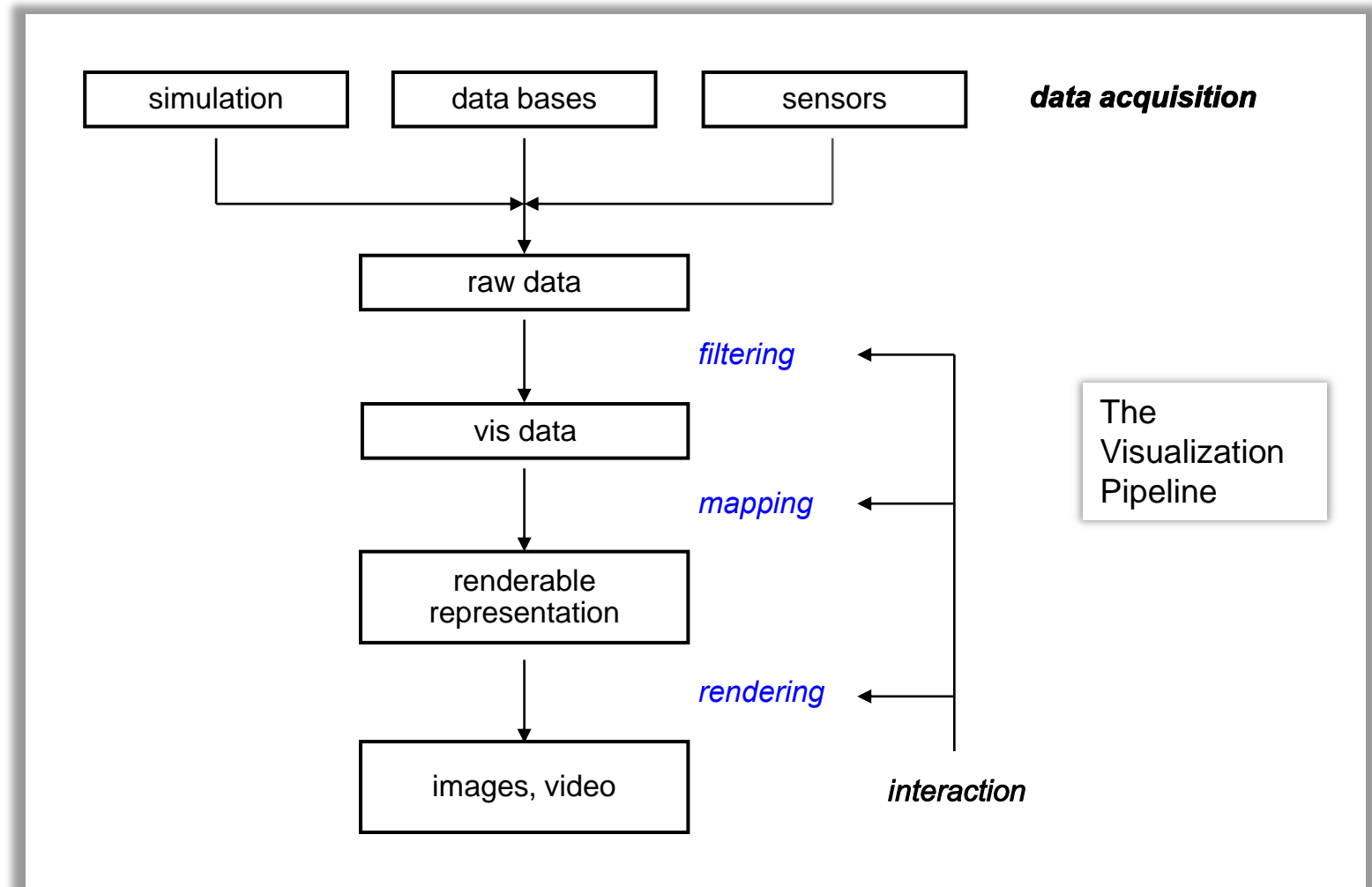
Expert

Done. Thanks.

Non-Expert

What is this?

- The process of converting data to images contains the steps: Filtering, Mapping, Rendering





Beskow

- supercomputer hosted at KTH
- 2 Petaflops ($2 \cdot 10^{15}$)
- Sweden's fastest
- 32nd fastest worldwide (11/2014)



Simulate flow around airplane

Simulate 1 second:

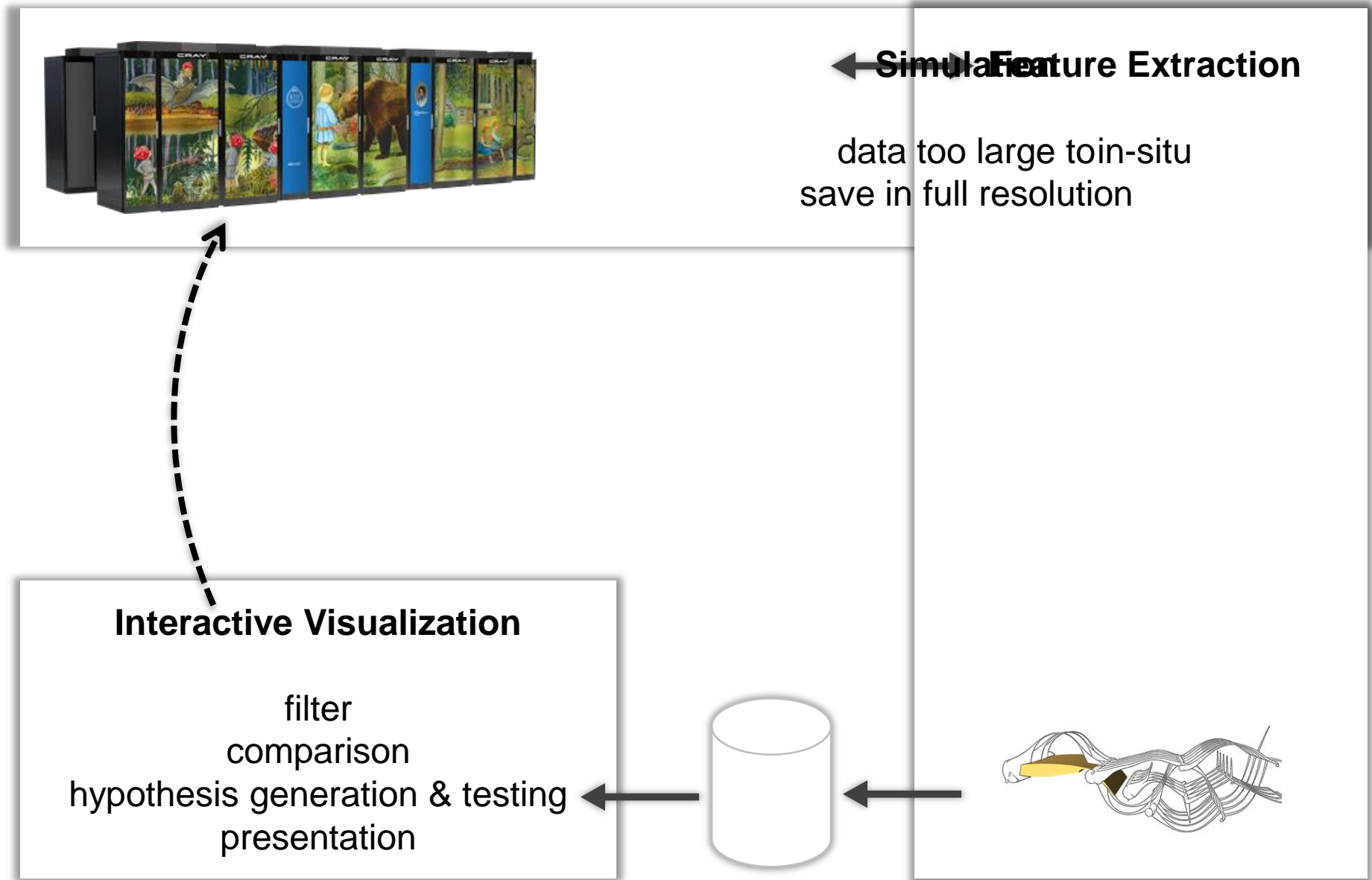
- 500 years computation time

Data size:

- 1 Terabyte of data per time step
- 100.000 time steps

-
- 100 Petabyte for one simulation

***data too large to save in
full resolution***



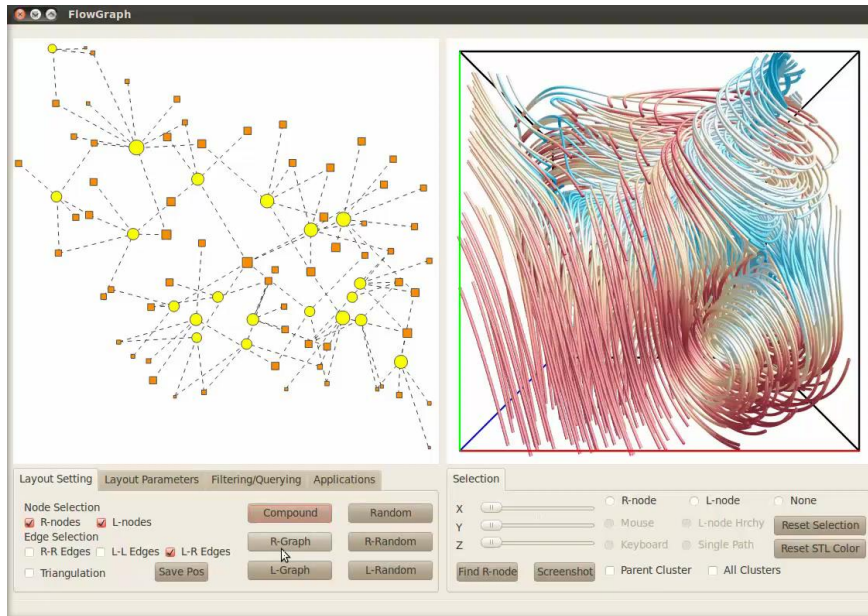
8:30 – 10:10

- Introduction Tino Weinkauff
- Talk 1: Jun Tao, Expressive Flow Field Exploration
- Talk 2: Bei Wang, Flow Analysis with Robustness
- Talk 3a: Tino Weinkauff, Spatio-temporal Flow Analysis

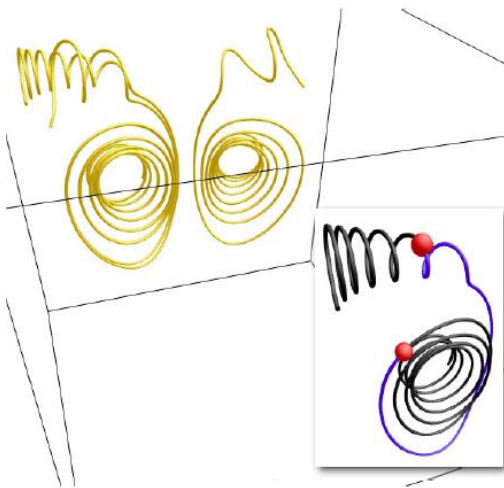
Coffee Break 20 minutes

10:30 – 12:10

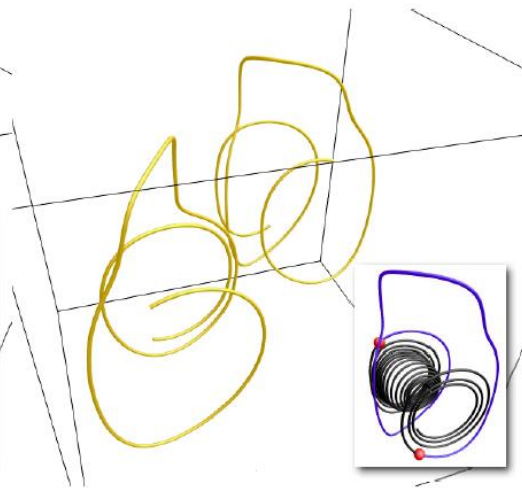
- Talk 3b: Tino Weinkauff, cont'd
- Talk 4: Christoph Garth, Vector Field Techniques for Large-Scale Data
- Talk 5: Hanqi Guo, Scalable Ensemble and Uncertain Flow Field Visualization
- Conclusion Christoph Garth



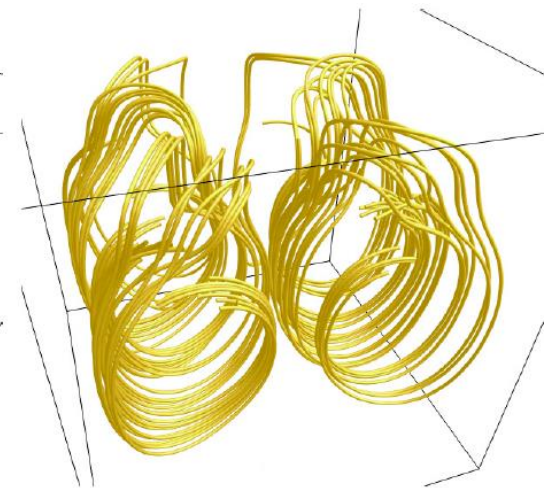
- Interactive flow exploration using features in the backend
- Queries for streamline patterns
- Flow Graph: Visual Analytics meets Flow Vis



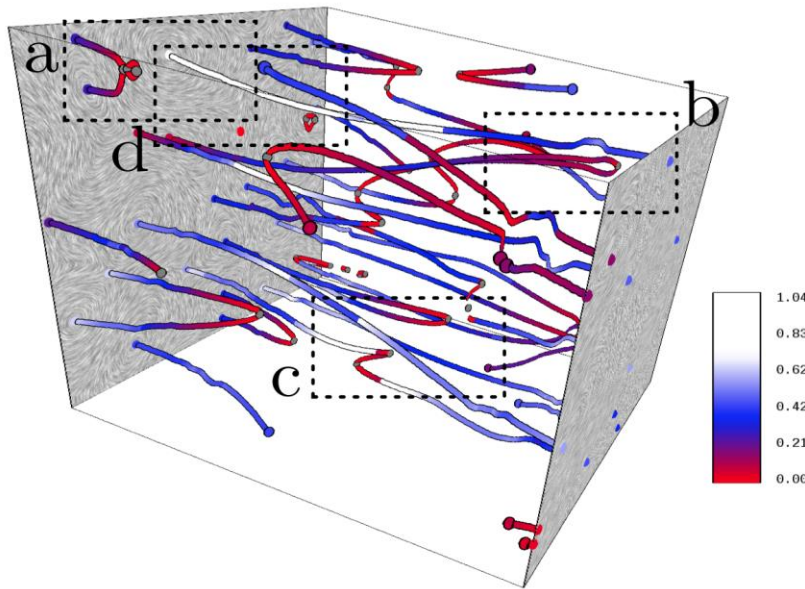
Query 1



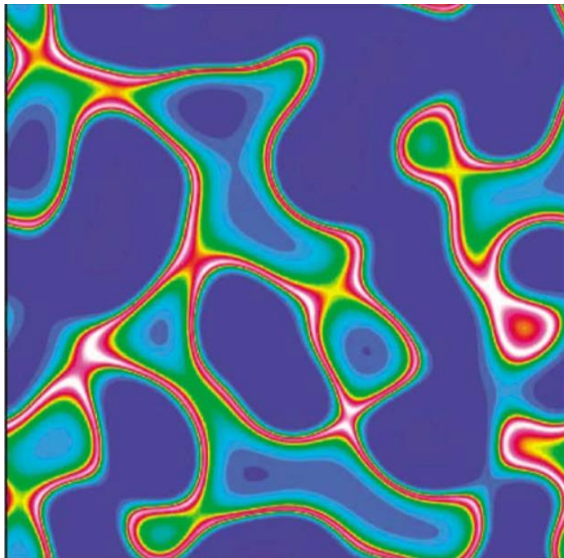
Query 2



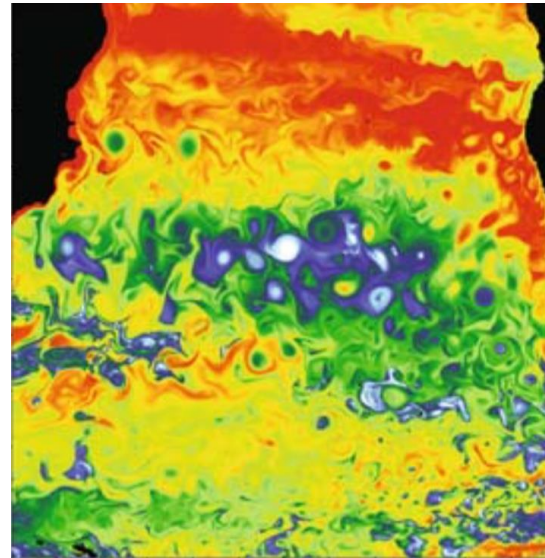
Query 2
(with approximation)



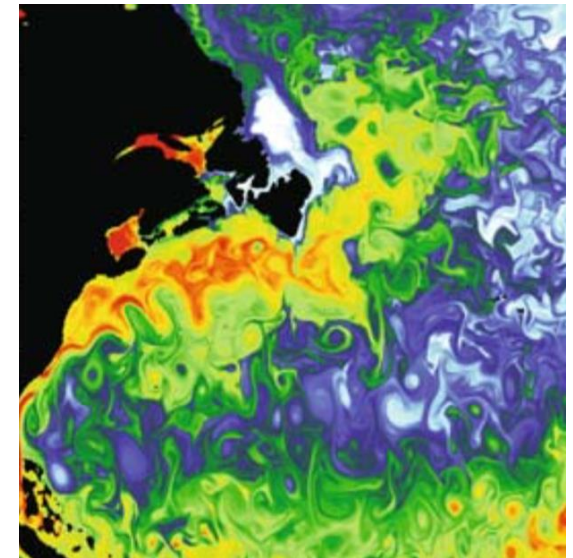
- Quantify stability of topological features: **Robustness**
- Separate features from noise at multi-scale
- Understand turbulent flow
- Feature extraction, tracking, and simplification

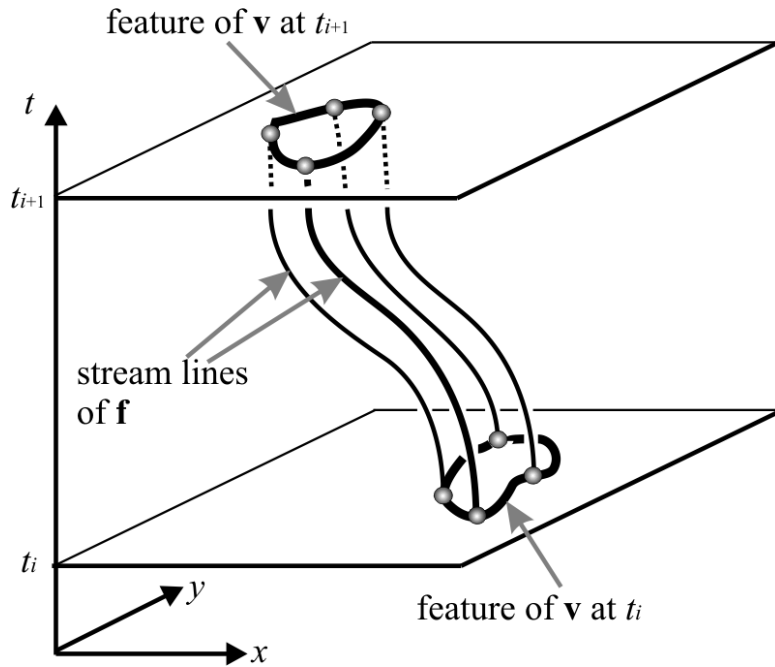


[Hawkes, Sankaran, Pebay, Chen 2006]

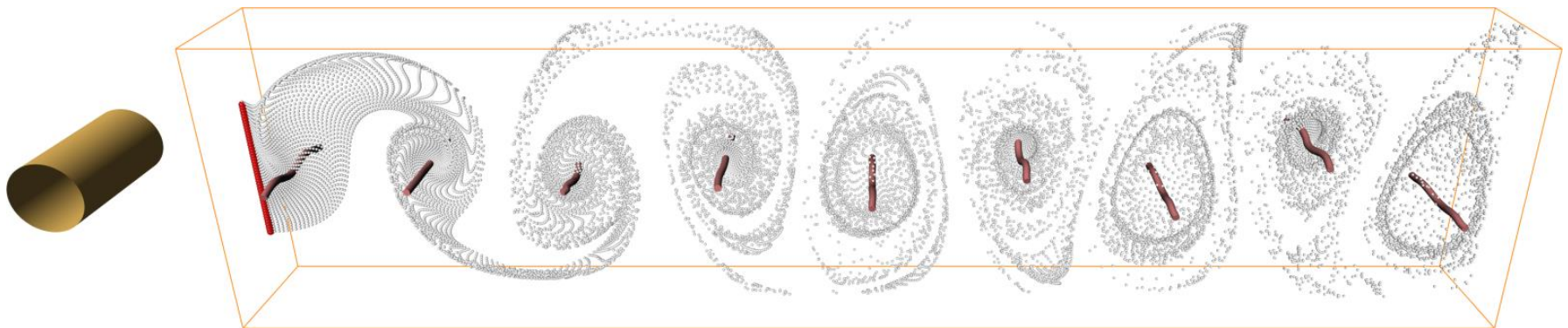


[Maltrud, Bryan, Peacock 2010]



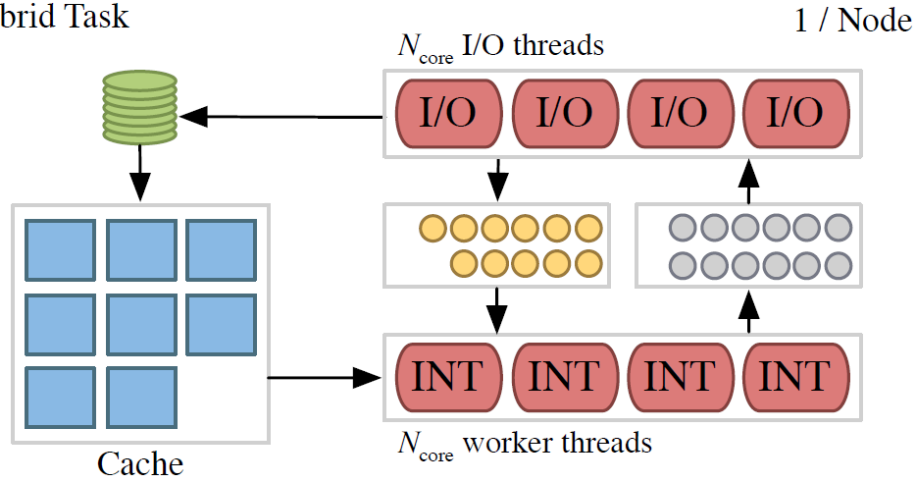


- Spatio-temporal formulation
- Advected Tangent Curves
 - Streak Lines as Tangent Curves
- Feature Flow Fields
- Parallel Vector Surfaces
- Swirling Motion Cores
- Inertial Flow Analysis

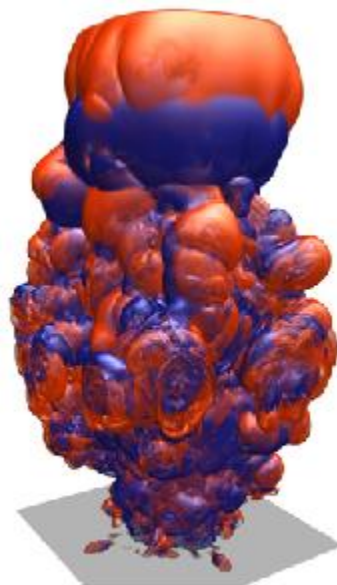


Swirling motion cores for path lines

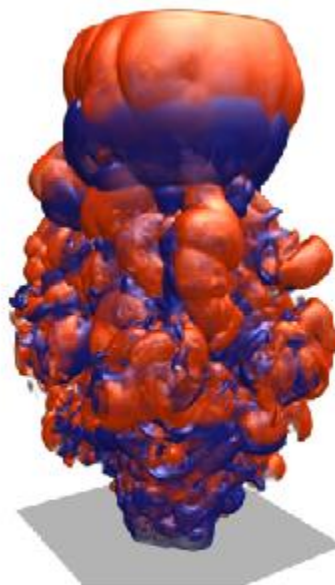
Hybrid Task



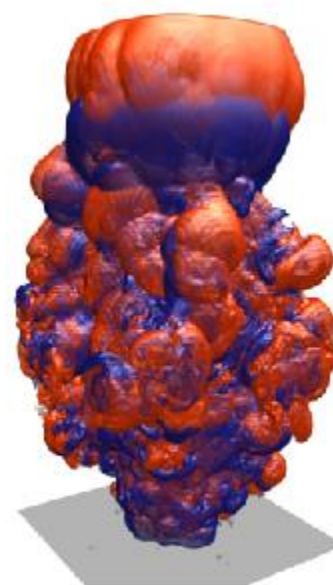
- Large-scale, time-varying flows
- Parallel algorithms
- In-situ techniques
- Flexibly analyze vector field data at reduced resolution



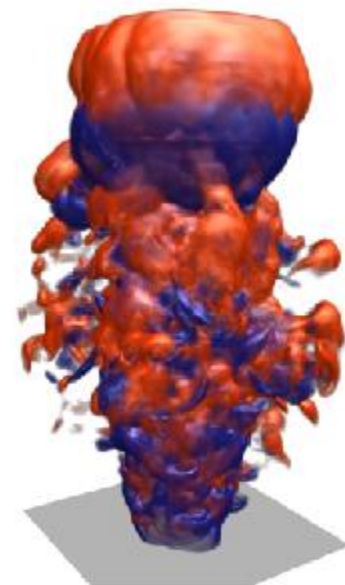
FD, 100% samples



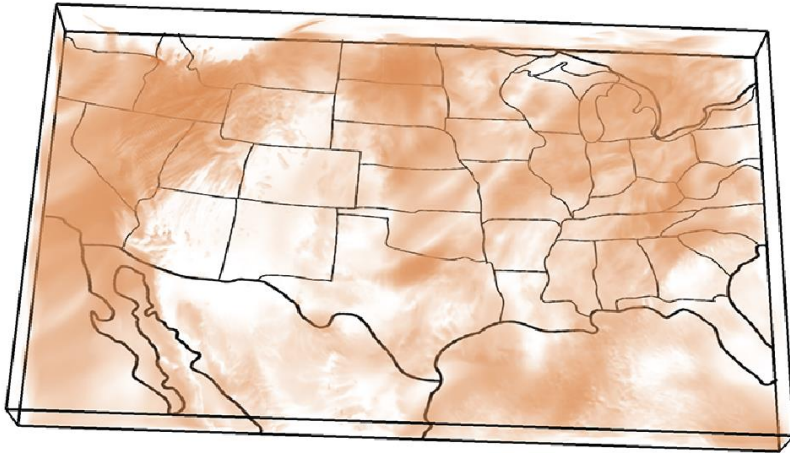
MLS, 1.5% samples



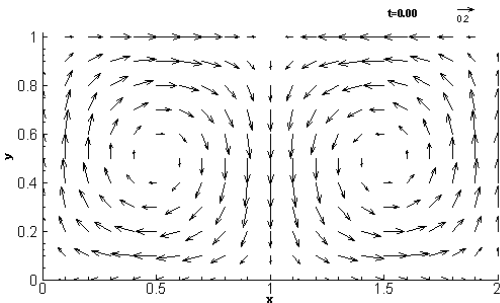
FD, 1.5% samples



MLS, 0.2% samples



- FTLE for uncertain/ensemble flows
- Performance and Scalability

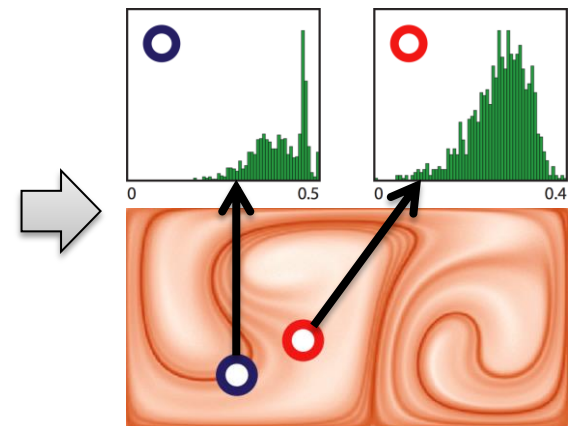


Stochastic particle tracing
(stochastic flow map)

$\sigma(\bullet)$



Stochastic FTLE runs



D-FTLE (mean)

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