Computer Graphics
and HCI Group

New Tasks for Visualization Research

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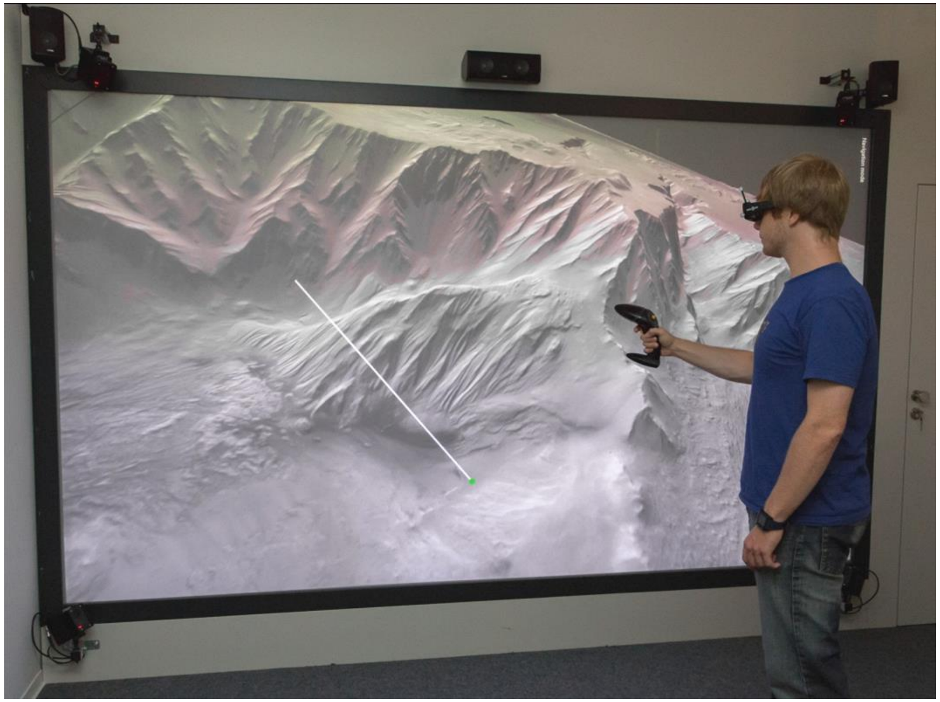
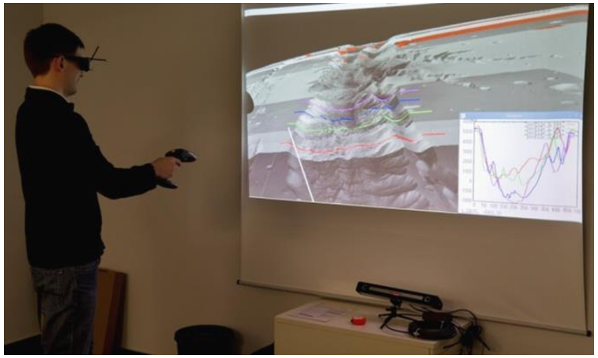
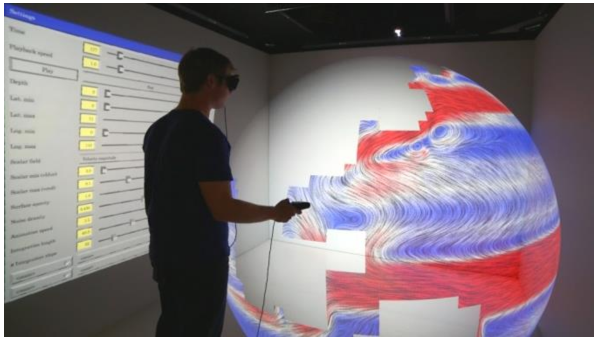
Scientific Visualization

- Problem: Geoscientific research uses 2D visualization
- Solution: Virtual-Reality visualization & analysis
  - For geologists (Mars) and oceanographers (ocean history)
  - Result: Advantages in perception of features and geometric relations, collaborative discussion

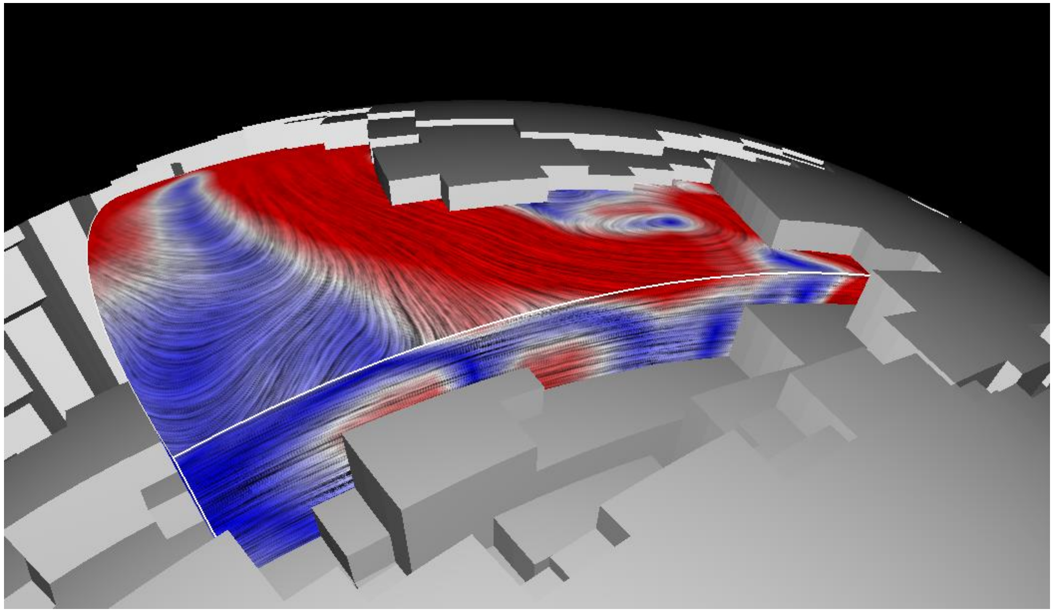


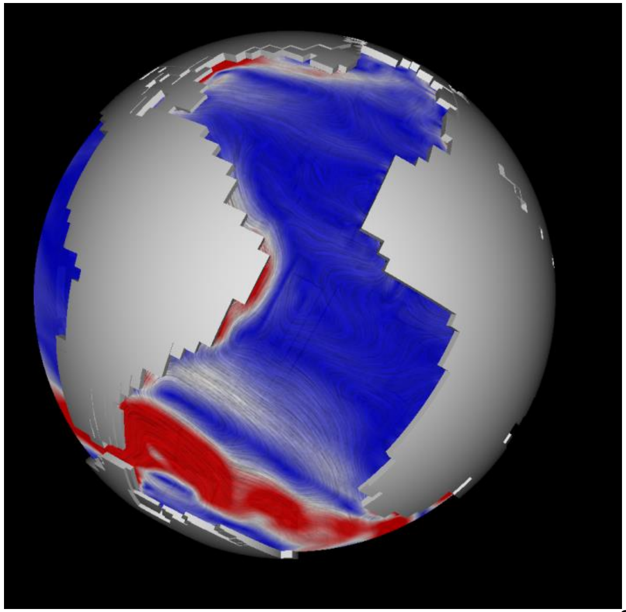




Visualization of Oceanographically Data

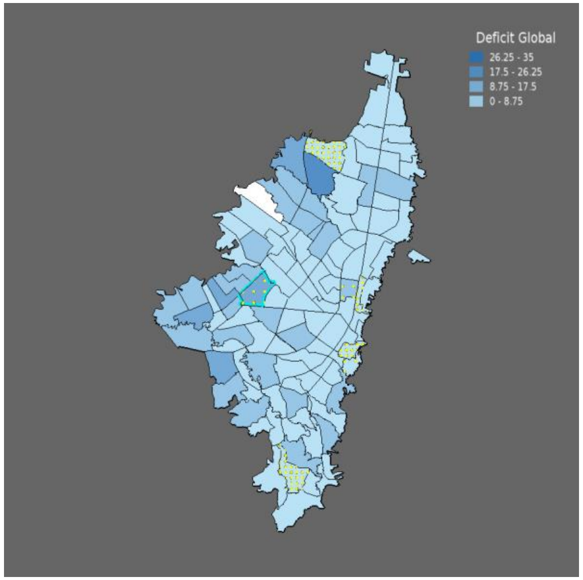
- Problem: Approximation of coarse and scattered Data to reconstruct and increase understanding changes of ocean currents during the last 20.000 years
- Challenges: Development of approximation-schemes that
  - Take physical properties and laws into account
  - Reconstruct modern observations from very sparse data

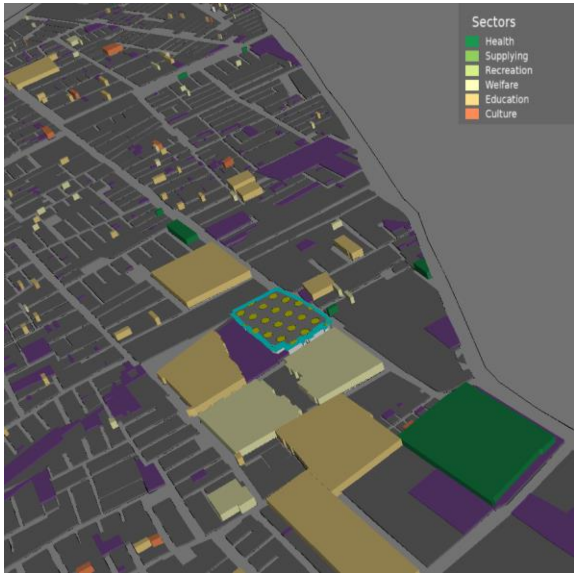




Information Visualization

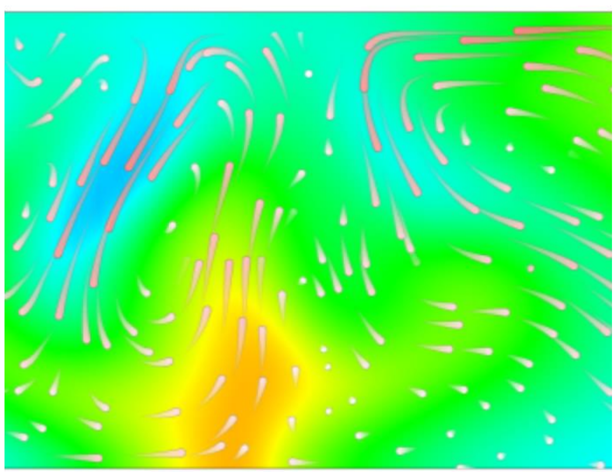
- Problem: Visualization of data quality dimensions to support urban planning process
- Solution: Enhanced visualizations including data quality
  - Improving the existing visualizations
  - Proposing new visualizations

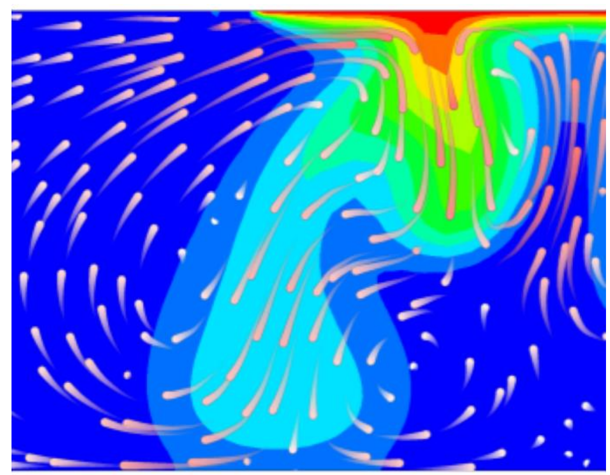




Geovisualization

- Problem: Intuitive Visualization of Transient Groundwater Flow
- Solution: STRING 2 – Vector field visualization by pathlets
  - Intuitive animation for audiences without background in groundwater modeling
  - Intelligent time-dependent pathlet seeding and management preventing optical holes and accumulations



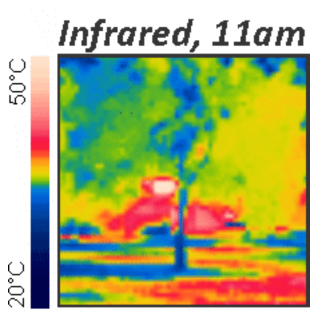


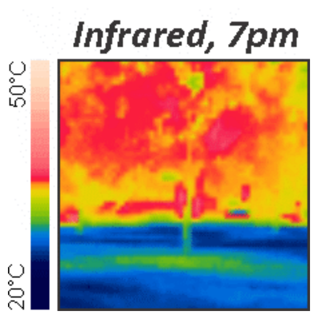
Visual Analysis

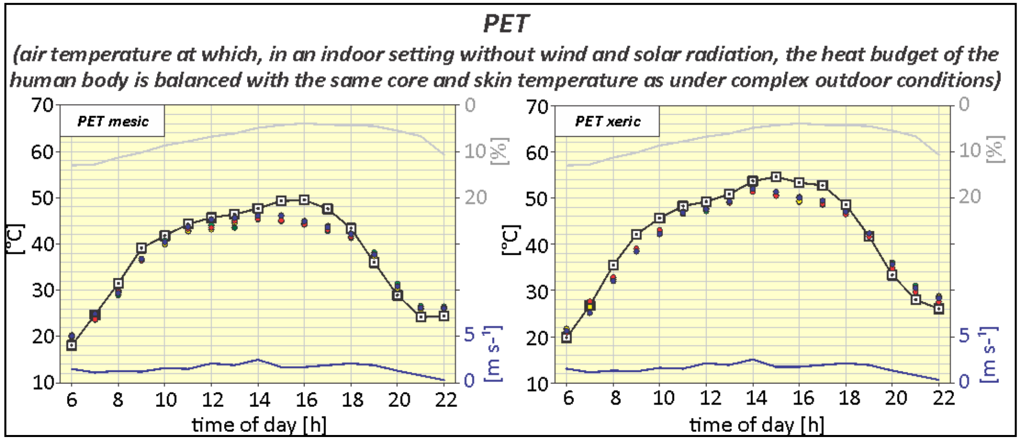
- Derivation and Visualization of Energy-Consumption in Arizona
  - Exploration of huge energy datasets
  - Web-based 3D-visualization software for modern browsers

Urban Climatology

- Problem: Do trees increase thermal comfort in a desert city (Phoenix, Arizona)?
- Solution: Infrared imagery, microclimate measurements and modeling
  - Simulate thermal comfort dynamics under selected tree species and on two different surface covers based on measurements
  - Result: Trees cause cooling on daytime and heat retention at night – thermal comfort on two surface covers differs by 33% in the afternoon

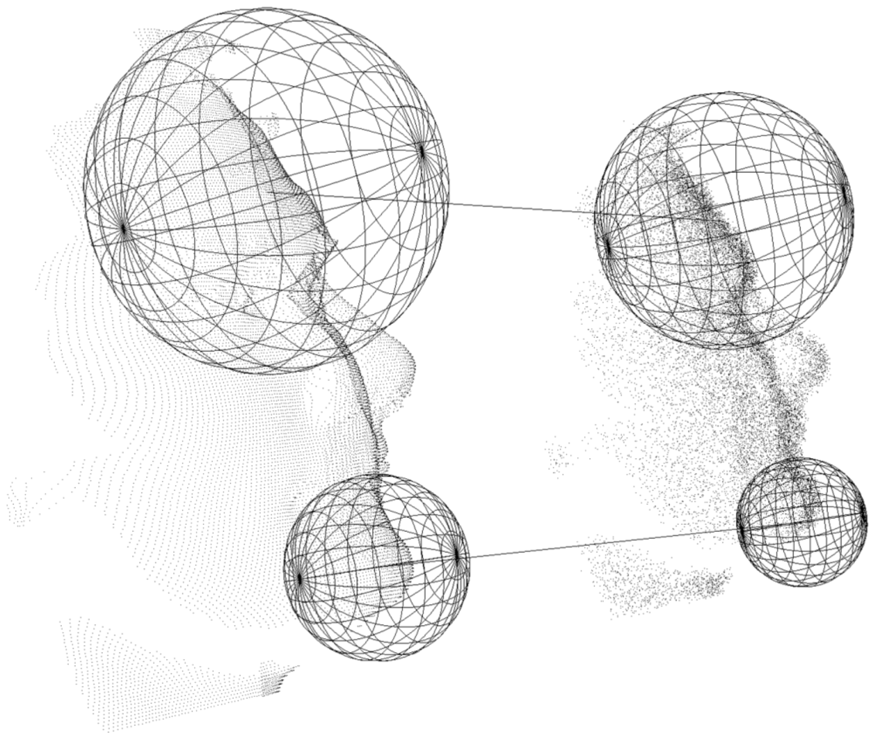


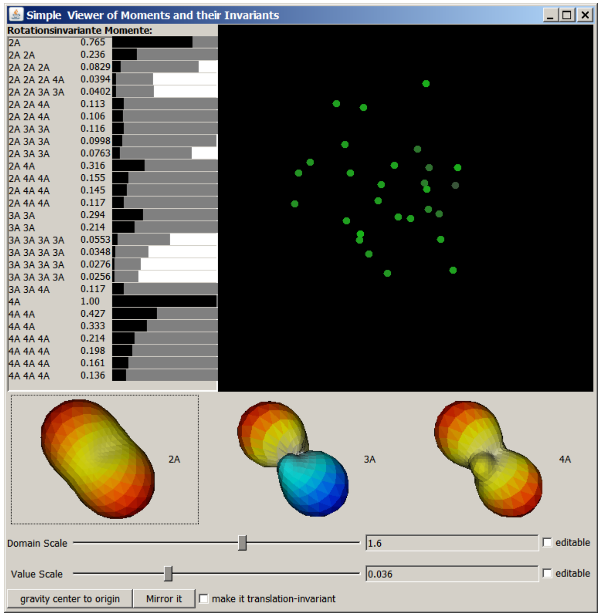




Object Recognition

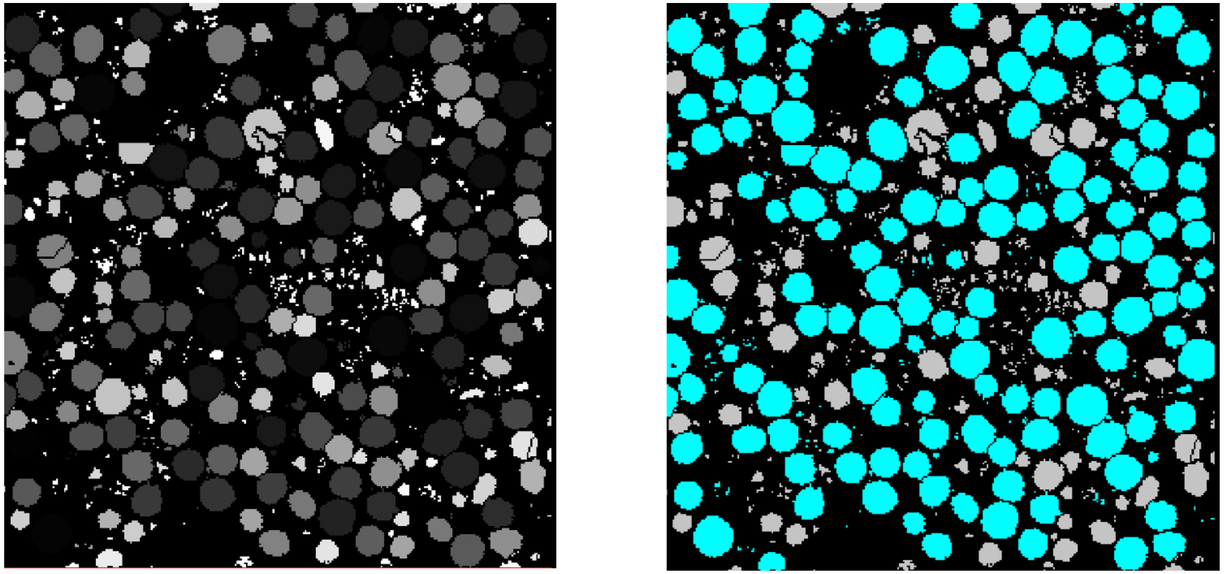
- Problem: find objects in noisy point cloud data
- Solution: higher-order rotational moment invariants
  - Calculate 4th-order moment's invariants from point distribution, compare them to stored invariants.
  - Result: recognition quite robust against noise





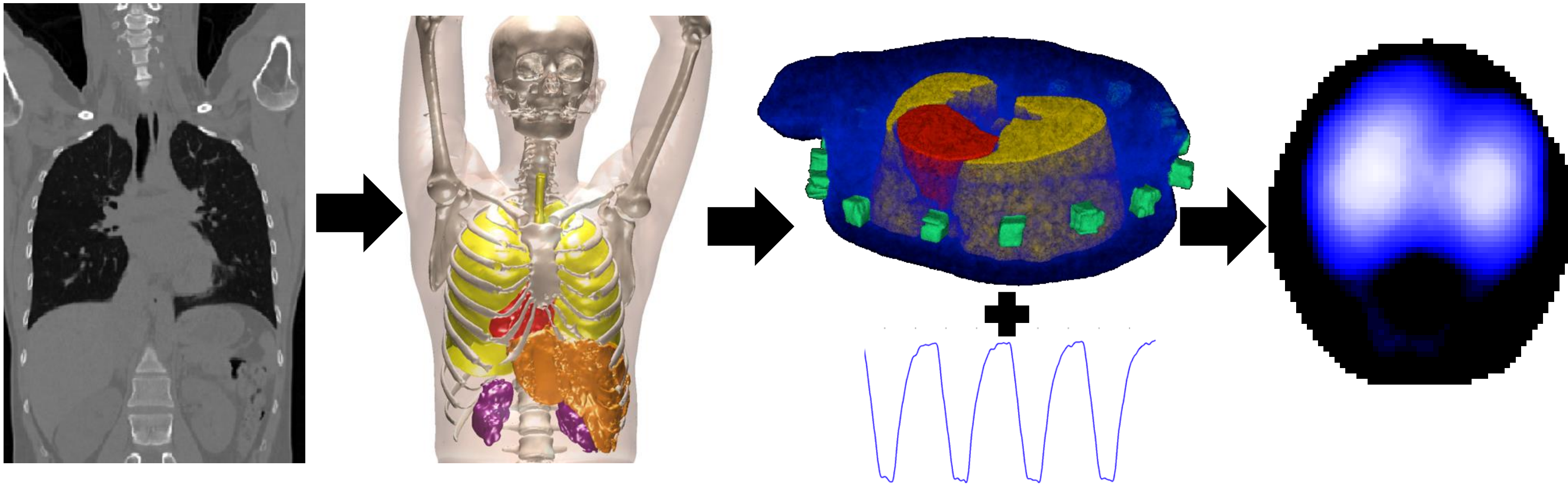
Scientific Visualization

- Interactive Feature Based Clustering and Classification
  - Clustering and classification of real data from various domains
  - Example: partition of elements into groups
  - Example: analyzing micro- and nanostructures of materials



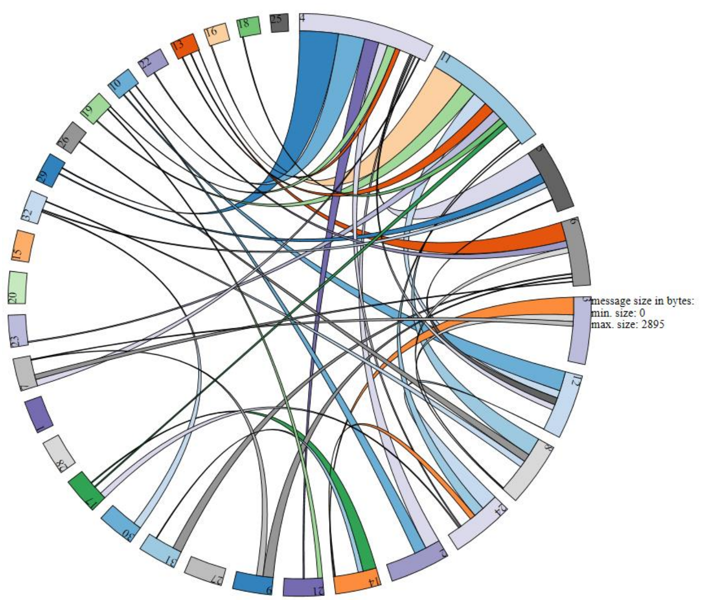
Medical Image Processing

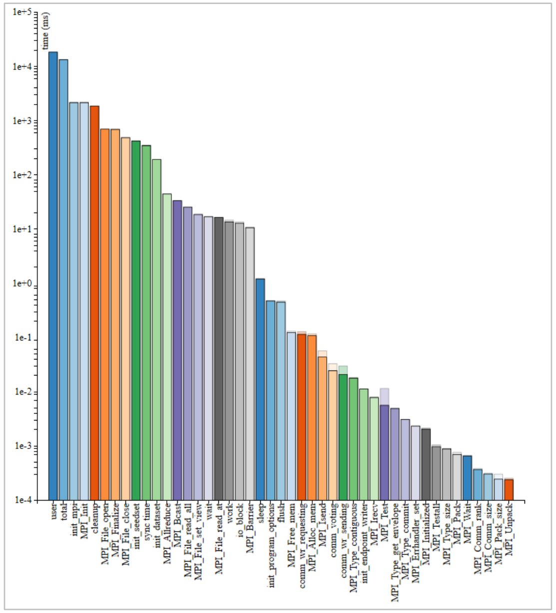
- Problem: Time-dynamic imaging of the lung function using Electrical Impedance Tomography (EIT) suffers from inaccurate and simplistic thorax models.
- Solution: Patient-specific 3D models from CT Scans
  - Workflow for multi-material segmentation of CT scans
  - Model generation, EIT image reconstruction, registration with CT data for anatomical correspondence



Information Visualization

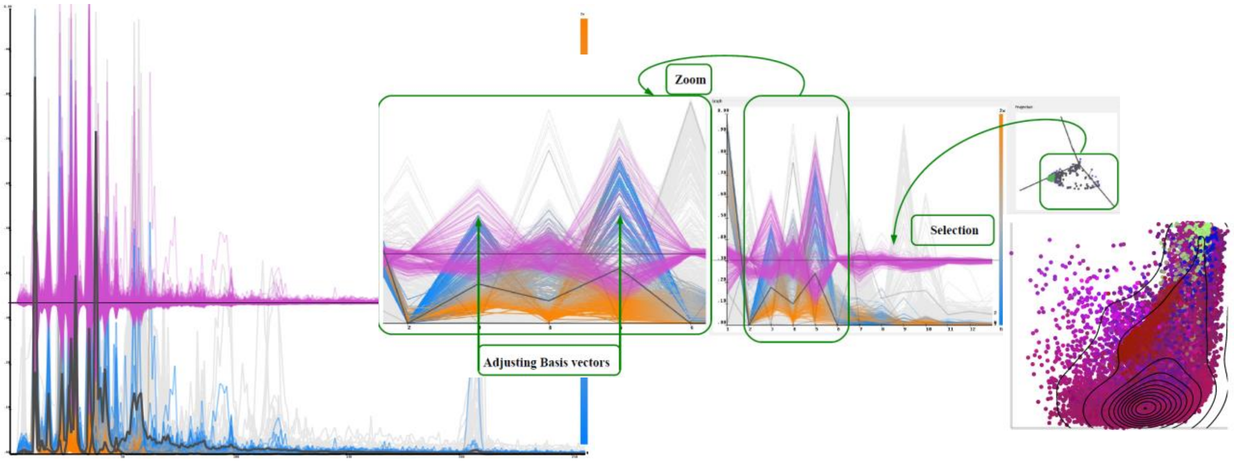
- Problem: communication and function analysis of parallel program traces
- Solution: Web-based interactive visualization
  - Statistical processing of trace data and visualization
  - Result: highly interactive visualization enabling fast comprehension of code behavior





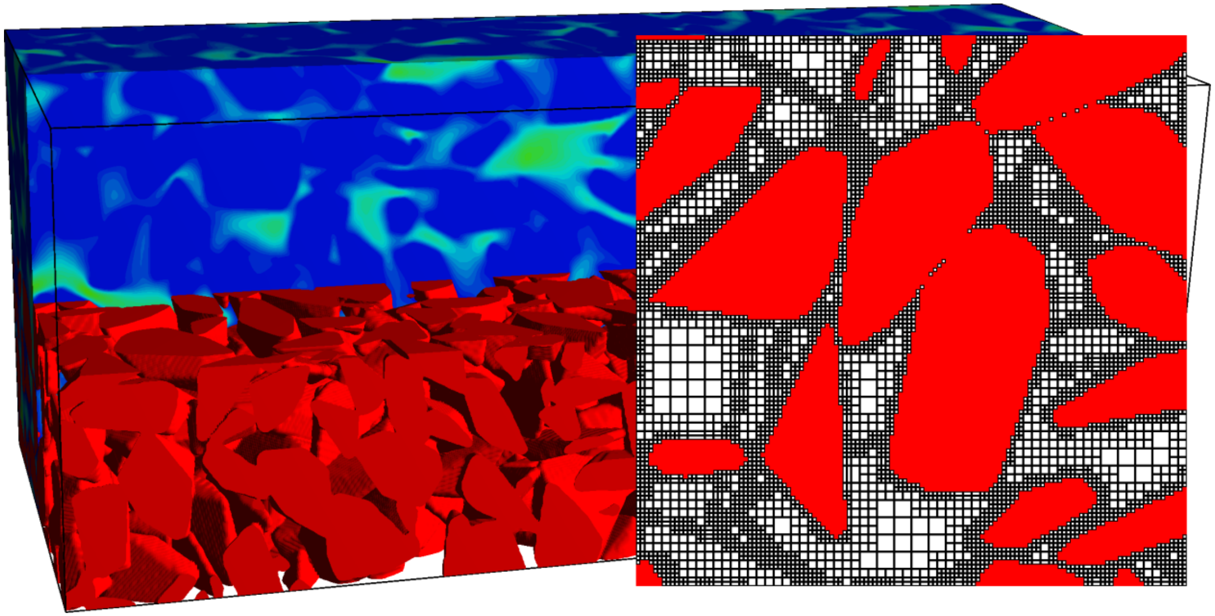
Visual Analysis

- Problem: analysis of physically complex phenomena often involve non-convex optimization on high-dimensional data, resulting in ambiguous and sub-optimal solutions that are hard to interpret.
- Solution: Model-based visual analysis
  - Semi-automatic optimization based on physical models, coupled with visual interface for computational steering
  - Intertwined error quantification and analysis
  - Result: higher-quality optimization by incorporation of domain knowledge; verifiable and interpretable solutions



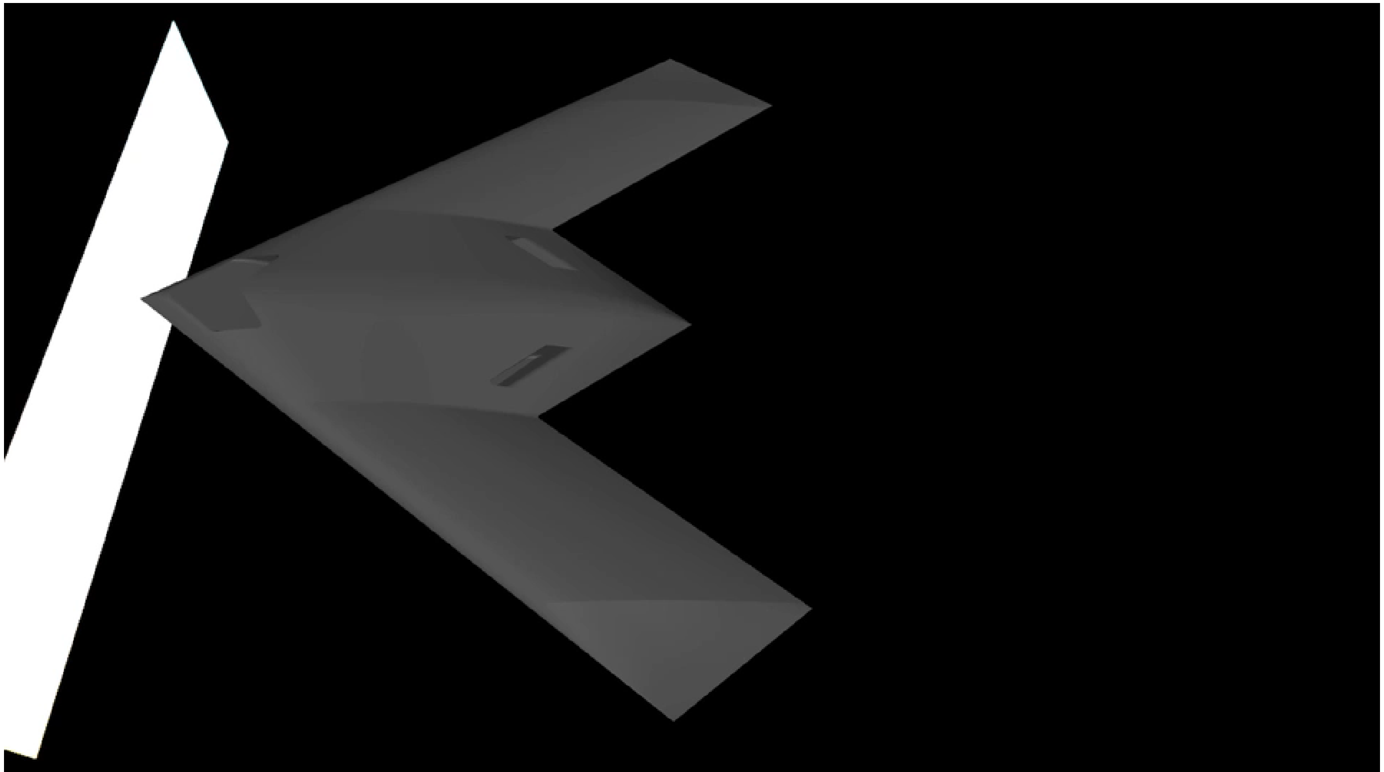
Computational Fluid Dynamics

- Problem: Fast and memory efficient numerical solving of the Stokes equations on very large geometries
- New concept and implementation: LIRStokes
  - Adaptive data structure with block linear systems
  - Result: Very fast, memory efficient and extensible to other partial differential equations



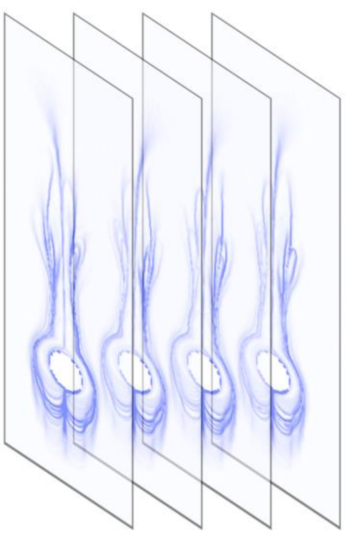
Flow Visualization

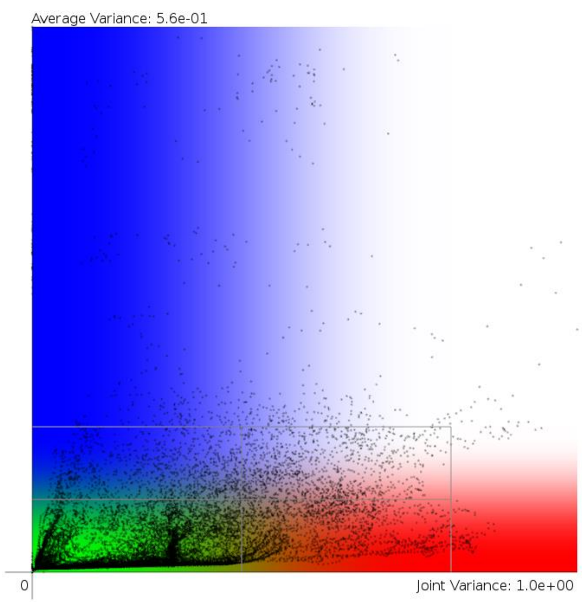
- Problem: Exploration of time-varying flow datasets
- Solution: Particle-based visualization as an effective tool
  - Fast algorithms for particle tracing
  - Direct particle visualization
  - Advanced methods, e.g. Integral Surfaces

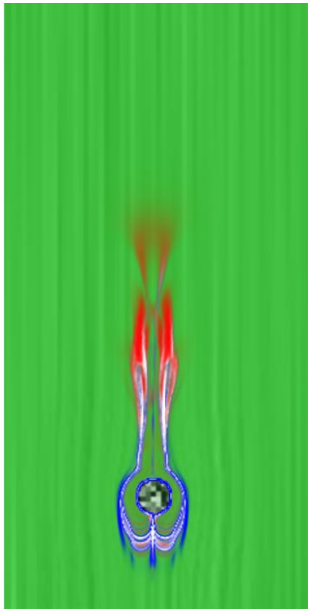


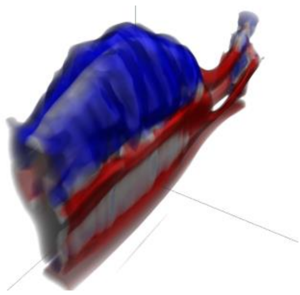
Flow Visualization

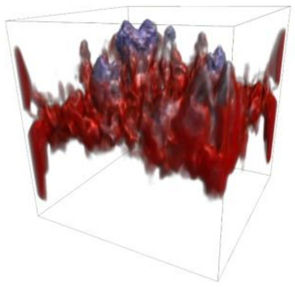
- Setting: Large number of simulation runs (*ensemble*) with similar parameters to capture physical phenomena.
- Task: compare particle transport behavior of these runs
- Approach: Comparative visual analysis using a classification space defined using variances of particle displacements





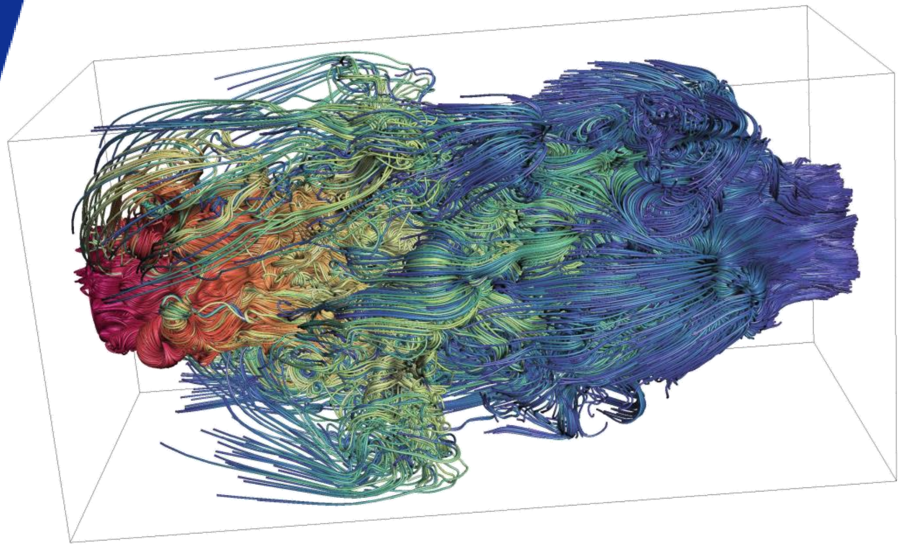


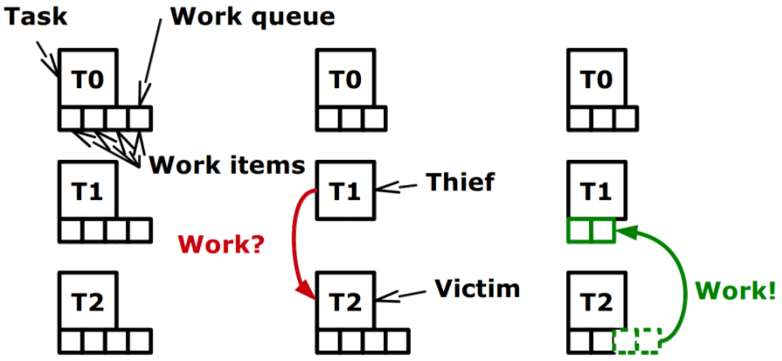




Large Data Visualization

- Problem: Integration-based visualizations of large datasets are hard to calculate efficiently on high performance computers
  - Distribution of data unclear
- Solution: Use dynamic scheduling
  - Result: adapts to imbalanced workloads

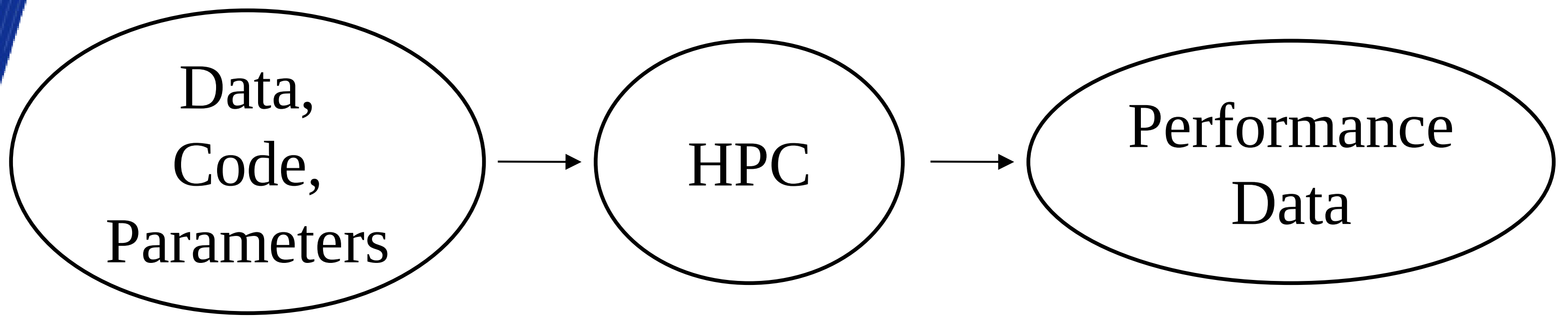




HPC Performance Analysis

Open Problems for Visualization?!

HPC Performance Analysis

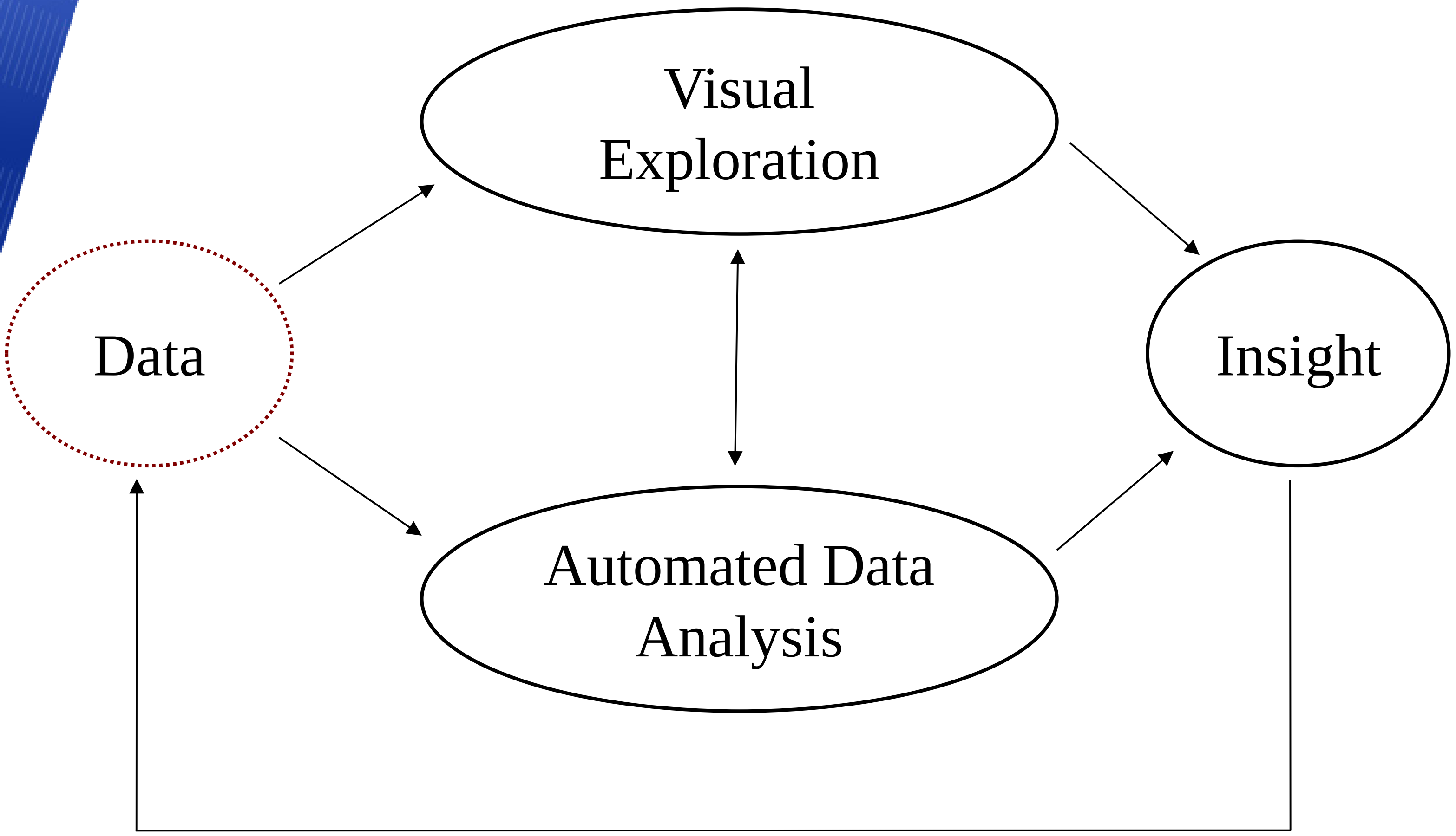


HPC Performance Analysis

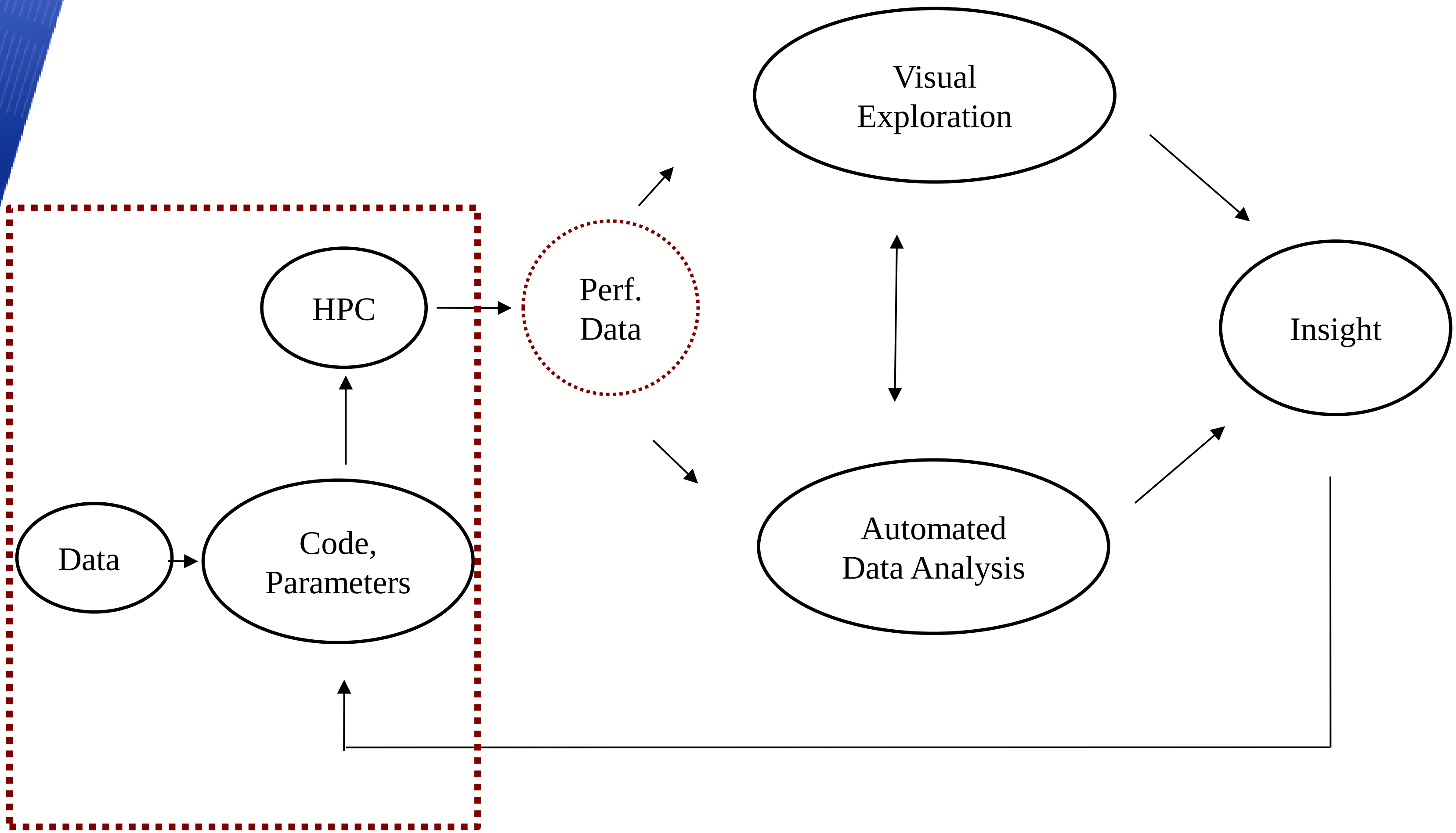
The interesting question to be answered in visual analysis:

»Where is efficiency lost?

HPC Performance Analysis



HPC Performance Analysis



HPC Performance Analysis

Problems due to very large data sets

»Algorithmic challenges (interactive exploration and analysis)

»Technical challenges (software integration, data streaming, bottle necks)

Not unique to HPC performance analysis!

HPC Performance Analysis

The interesting question to be answered in visual analysis:

»*Where is efficiency lost?*

This question is too unclear & not defined well enough!

Unclear from a visualization perspective:
»What is the mathematical characterization of the objects involved in HPC performance analysis?

How does Performance Data fit in with existing VA machinery?

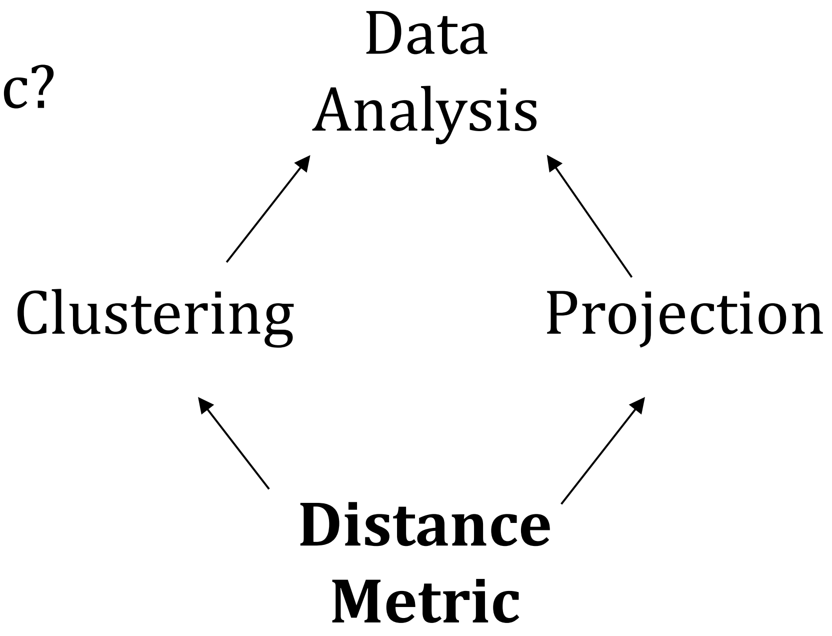
HPC Performance Analysis

How is performance data described mathematically?

»**Space**

For example:

What is the right metric?

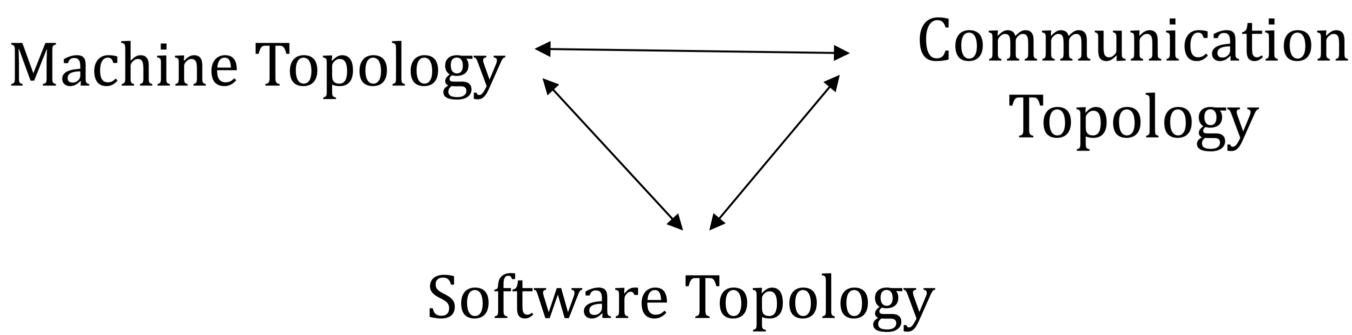


HPC Performance Analysis

How is the system and software described mathematically?

»**Topology**

For example:
What are the interrelations?



HPC Performance Analysis

Data quality measures:

»**Accuracy, Completeness, Consistency, Reliability, Availability, Currency, Timeliness, ...**

Performance as part of Quality?

- online quality control / monitoring

- Connection to Fault Tree Analysis?

Vector and Tensor Bundles

A tool for Scientic Visualization?

Vector- and Tensor bundles

Geometry and topology are the basic technologies for geometric modelling and scientific visualization. I will present in this talk ongoing research topics.

Vector- and Tensor bundles

Some basic concepts and facts:

- A manifold M of dimension n is a topological space with the following properties

Computational Topology

Vector- and Tensor bundles

- (i) M is a Hausdorf Space

  (ii) M is locally Euclidean

  (iii) M has a countable basis of open sets
- A topological manifold M is locally connected, locally compact and a union of a countable collection of compact subsets.
- => M is metrizable

Computational Topology

Vector- and Tensor bundles

- $T(M) := \bigcup_{p \in M} T_p(M)$ is a manifold called the tangent bundle of M
- A vector field on a manifold M is a function which assigns to each point $p \in M$ a vector $X_p \in T_p(M)$

Vector- and Tensor bundles

IDEA

We consider a vectoreld A = $\begin{bmatrix} A_1 \\ A_2 \end{bmatrix}$ being part of a tangent bundle of a Riemannian manifold (M, g) with a metric tensor:

$G_{ij} = g_{ij}$ + “Finsler metric“

Computational Topology

Vector- and Tensor bundles

“A Finsler space is not considered a point space but primarily as a set of line elements in which a Riemannian metric is associated with each line element.“