Visualization, DD2257

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Feature-based Methods


Milestones in Flight History
Dryden Flight Research Center
NASA
L-1011
Airliner Wing Vortice Tests at Langley
Circa 1970s

Feature

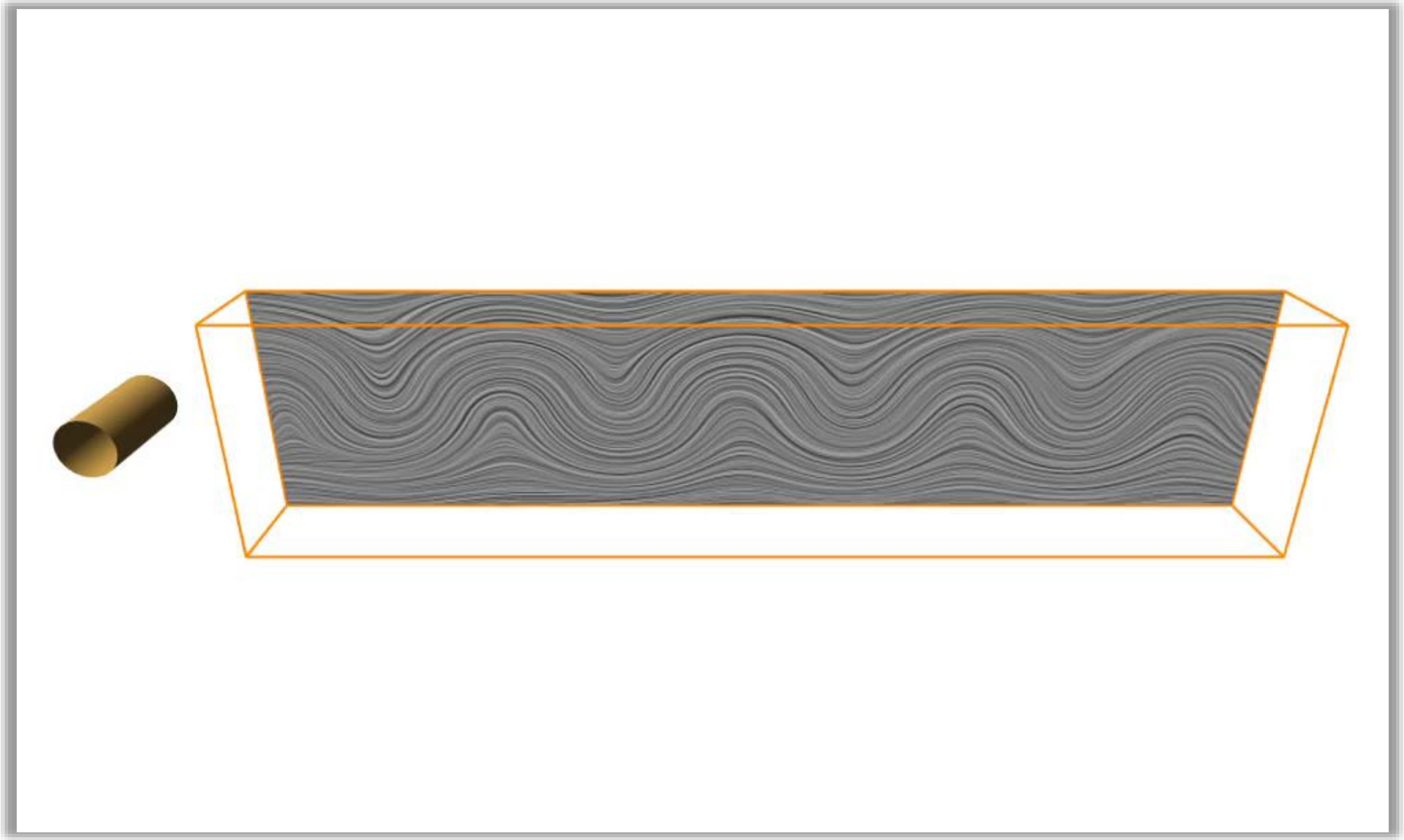
n-dimensional geometrical structure

embedded into m-dimensional domain

yields certain „insight“

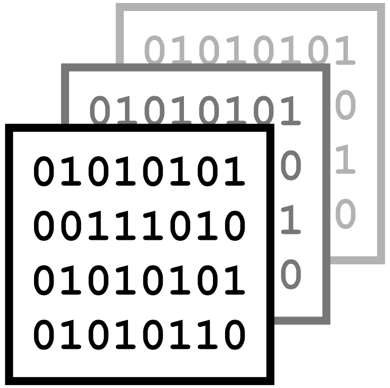
precise definition depends on application

often using generic building blocks



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

Data

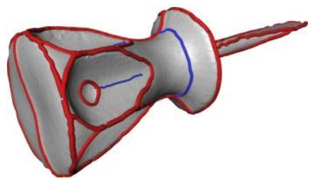


*Large data sets,
multi-run simulations,
parameter space,
3D scanners*

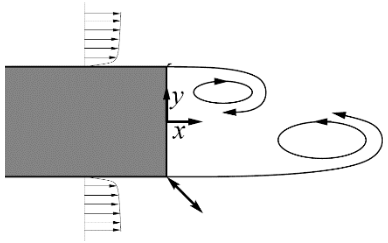
Analysis

*automated
target-oriented
objective*

Benefit



Shape descriptors



*Conceptual
flow models*

Feature-Based Data Analysis

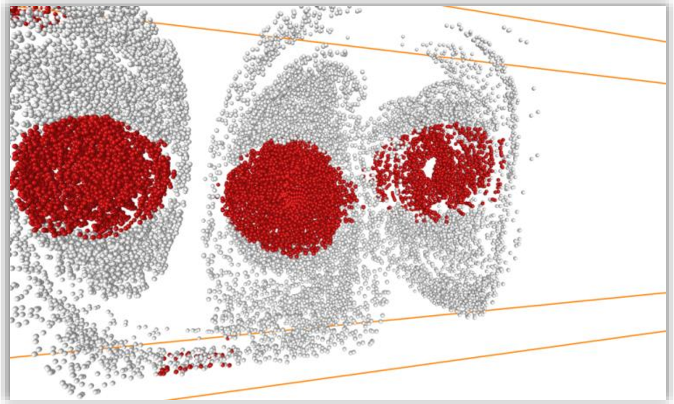
reduction of information

interactive visualization

faster analysis

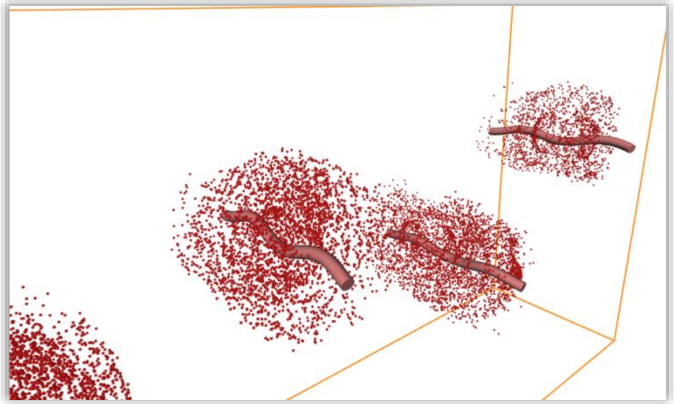
very important

Classic Visualization



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

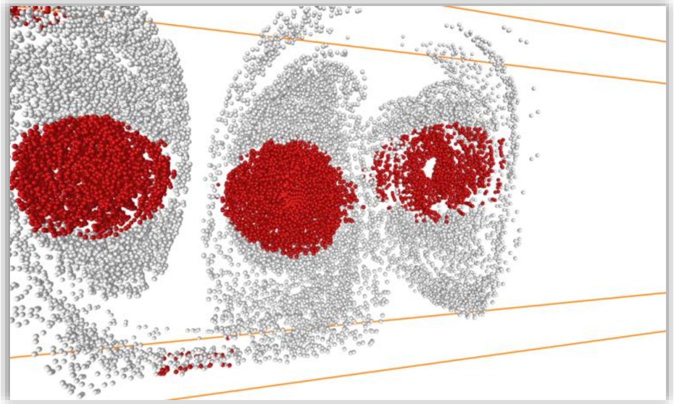
Feature-based Visualization



- 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

very important

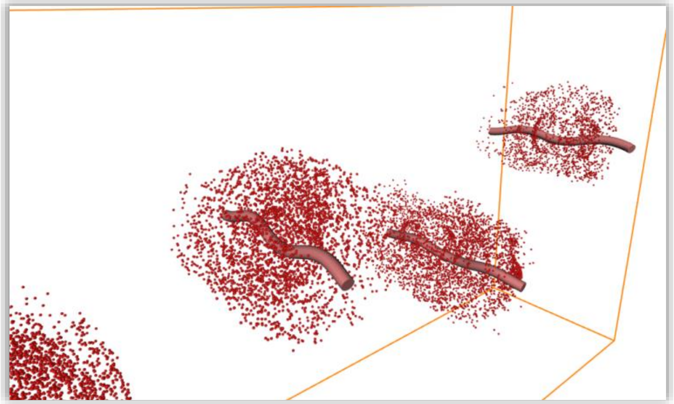
Classic Visualization



– Requires subjective interpretation of the image to find the most interesting parts of a data set

\+ Low cognitive load
“Easy to understand what is shown”

Feature-based Visualization



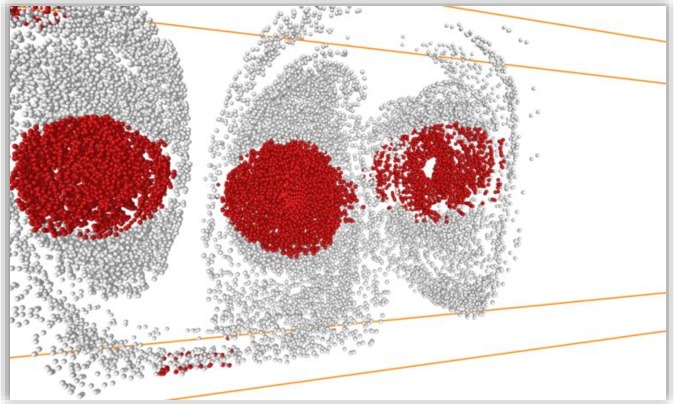
\+ Employs objective mathematical definitions to extract the most interesting parts of a data set

– Medium to high cognitive load
“Difficult to understand what is shown”

Disclaimer:
These are general remarks, which apply to most classic/feature-based methods, but not to all.
It depends on the specific method and the application.

very important

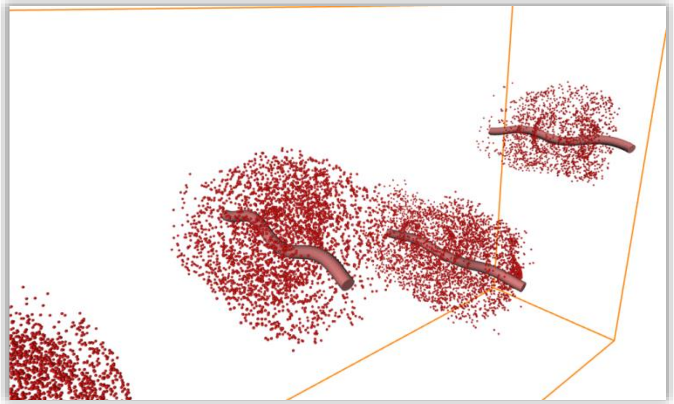
Classic Visualization



– Requires subjective interpretation of the image to find the most interesting parts of a data set

– Cannot be automated in a reasonable way. Therefore, difficult to use with very large data sets.

Feature-based Visualization



+ Employs objective mathematical definitions to extract the most interesting parts of a data set

+ Can be automated to run on a supercomputer (for example together with the simulation).

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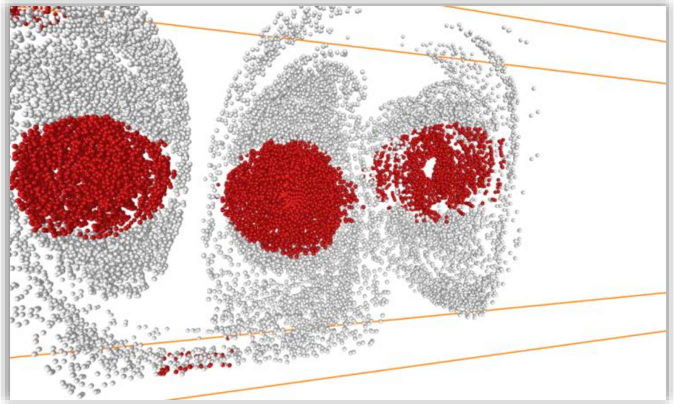
Classic Visualization

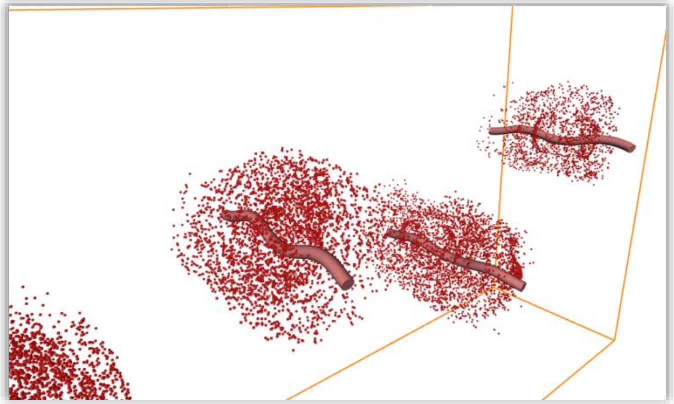


No automation and direct rendering of original data:

+ No pre-computation

– User needs more time for analysis

Feature-based Visualization



Automation and interactive rendering of the feature set:

– Pre-computation (feature extraction)

+ User needs less time for analysis

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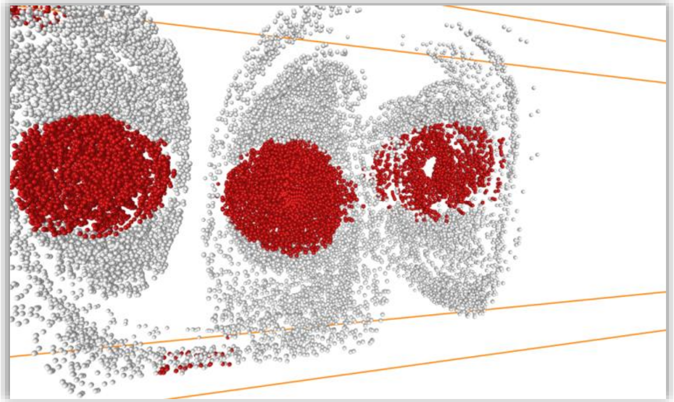
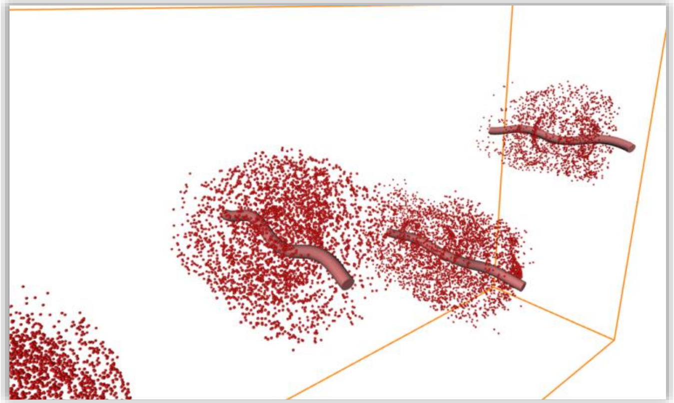
Classic Visualization



– Less data reduction. Often, all is shown.

Rendering can be slow or fast; depends on the method and the size of the data

Feature-based Visualization



+ Data reduction. Only a small set of geometric objects is shown.

+ Fast, interactive rendering

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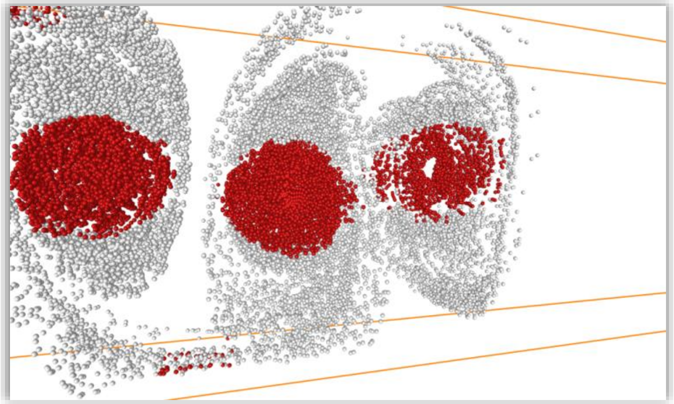
Classic Visualization

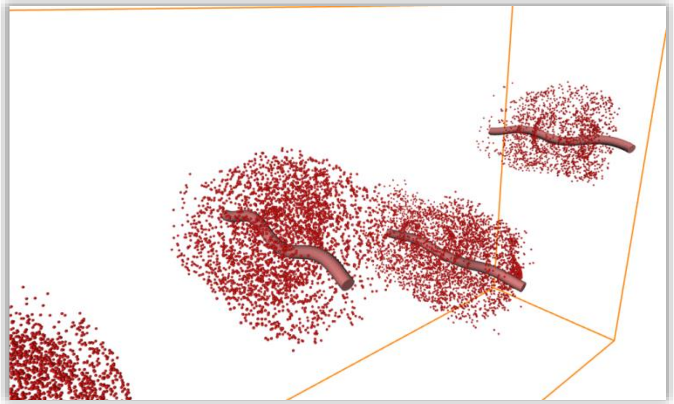


– No data reduction. Usually, all is shown.

– Experts need to dig through all the data.

+ Non-experts have the context they need for understanding.

Feature-based Visualization



+ Data reduction. Only specific aspects are shown.

+ Experts can concentrate on the most important parts.

– Non-experts need additional context to understand.

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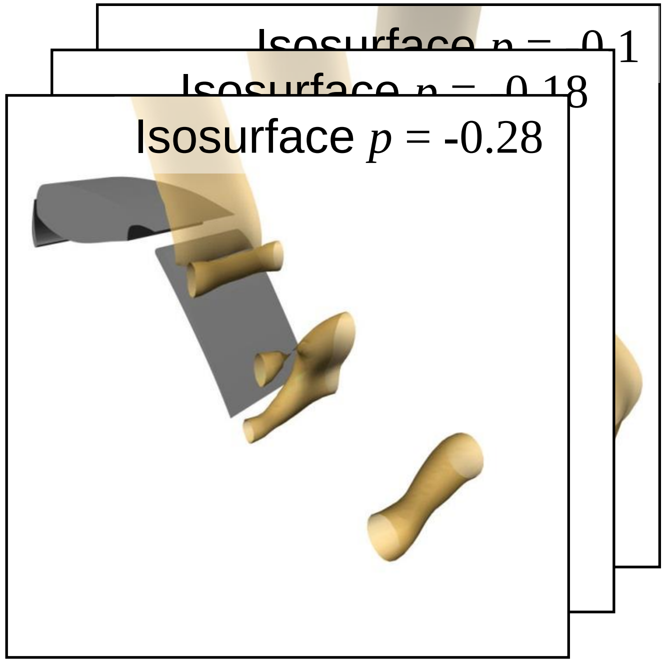
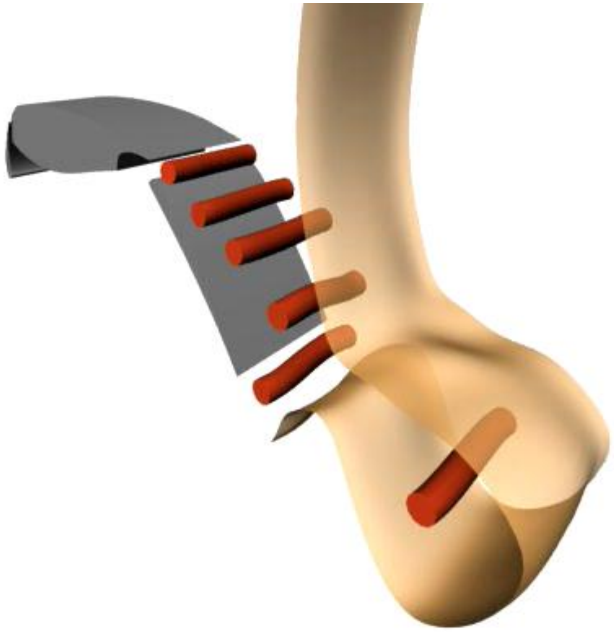
It depends on the specific method and the application.

Classic Visualization

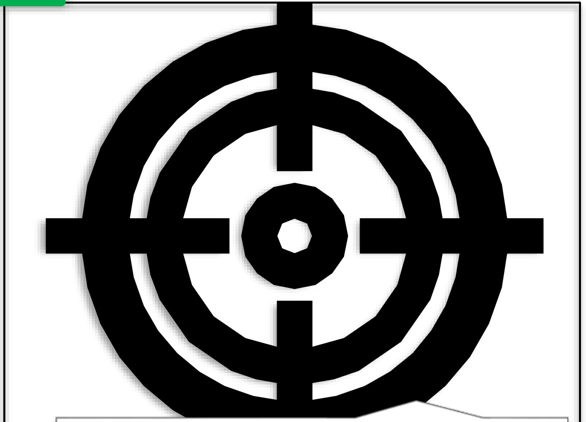


Feature-based Visualization

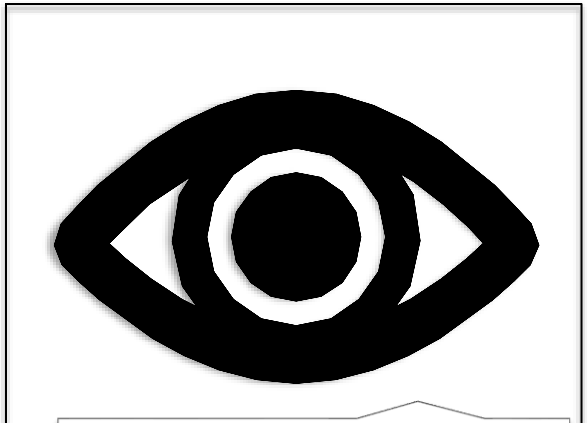


Classic Visualization		Feature-based Visualization
This is tedious, repetitive work! Did I miss something?	Expert	*Done. Thanks.*
Yes, I get the basic idea.	Non-Expert	*What is this?*

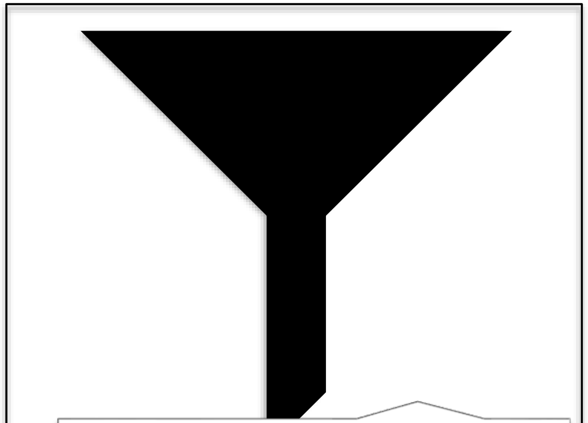
very important



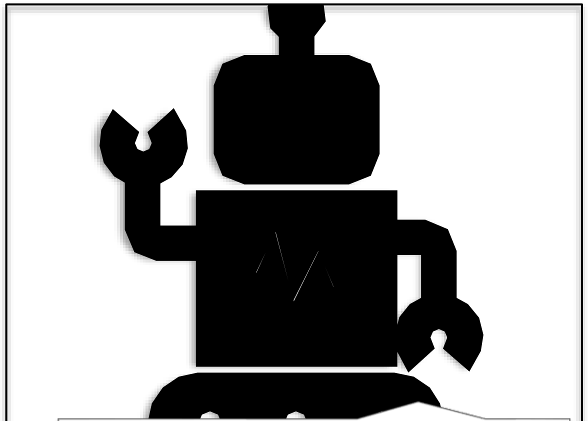
features are interesting structures in the data



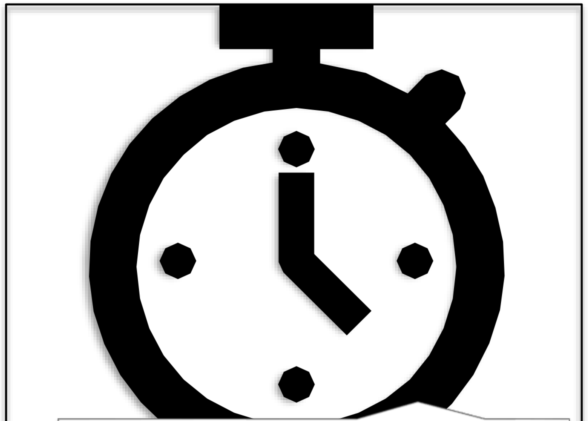
extract, track, visualize, run statistics



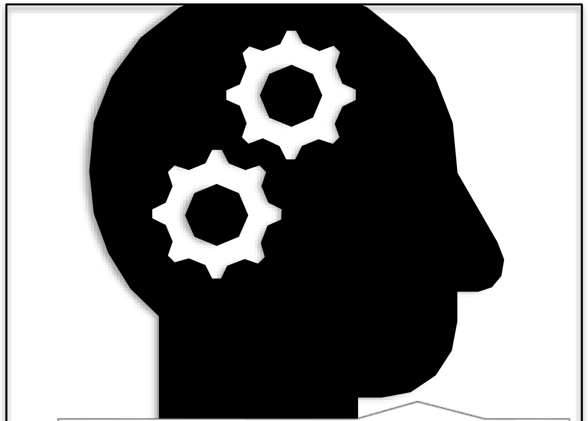
the original (large) field is not needed anymore for visualization



extraction can (usually) be automated



rendering is fast and (usually) interactive



medium to high cognitive load

Common Features

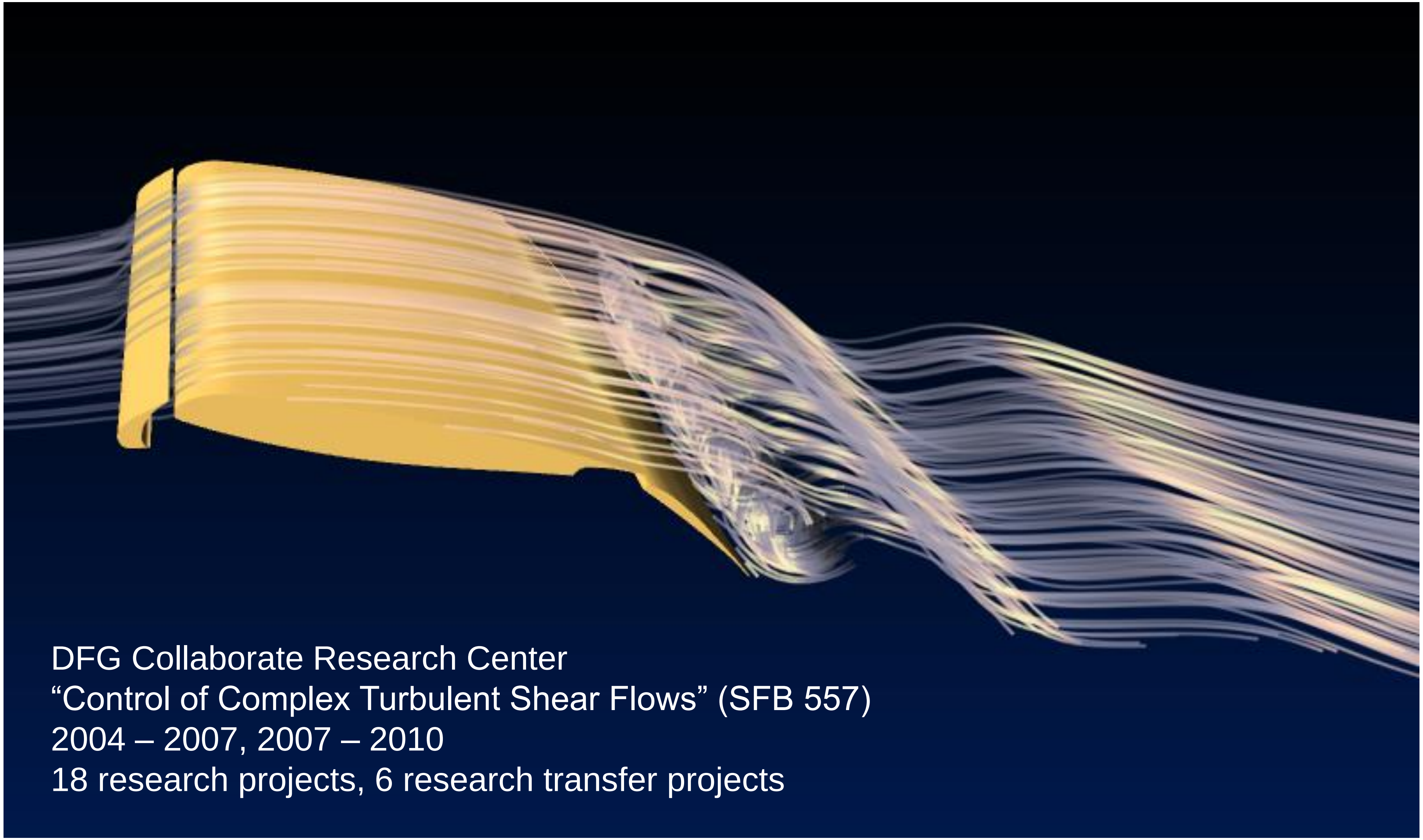
Application-dependent Features

- swirling motion in vector fields
  - vortices
  - eddies
  - cyclones
  - storms
- shock waves
- attachment/detachment lines
- cytoskeleton
- planetary topography

Theories and Building Blocks

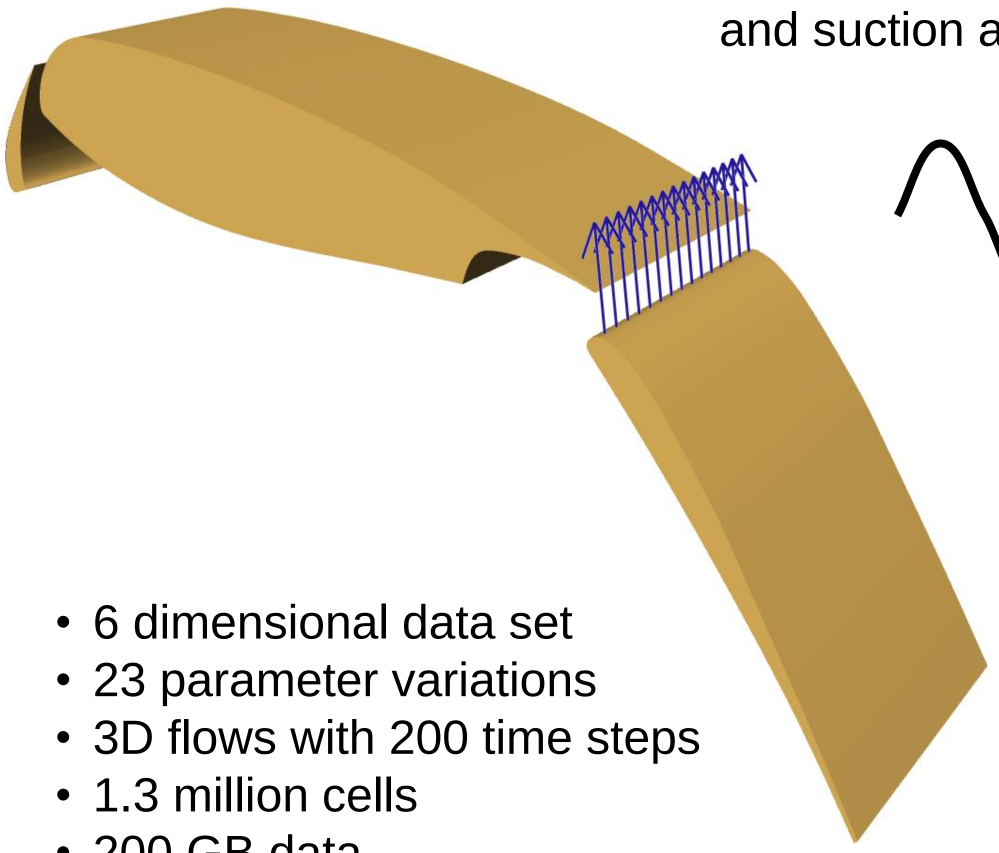
- Topology
- (Discrete) Morse theory
- Morse-Smale complex
- merge trees
- feature flow fields
- derivatives

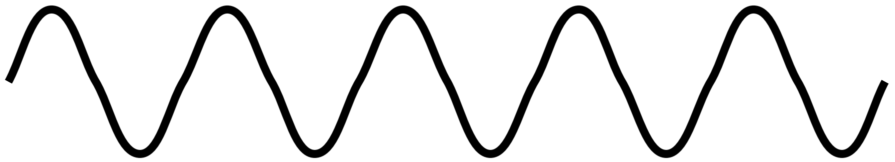
Example of a feature-based analysis and visualization



Flow around an airfoil. Data courtesy of Bert Günther (TU Berlin).

Excitation by periodic blowing
and suction at the rear flap



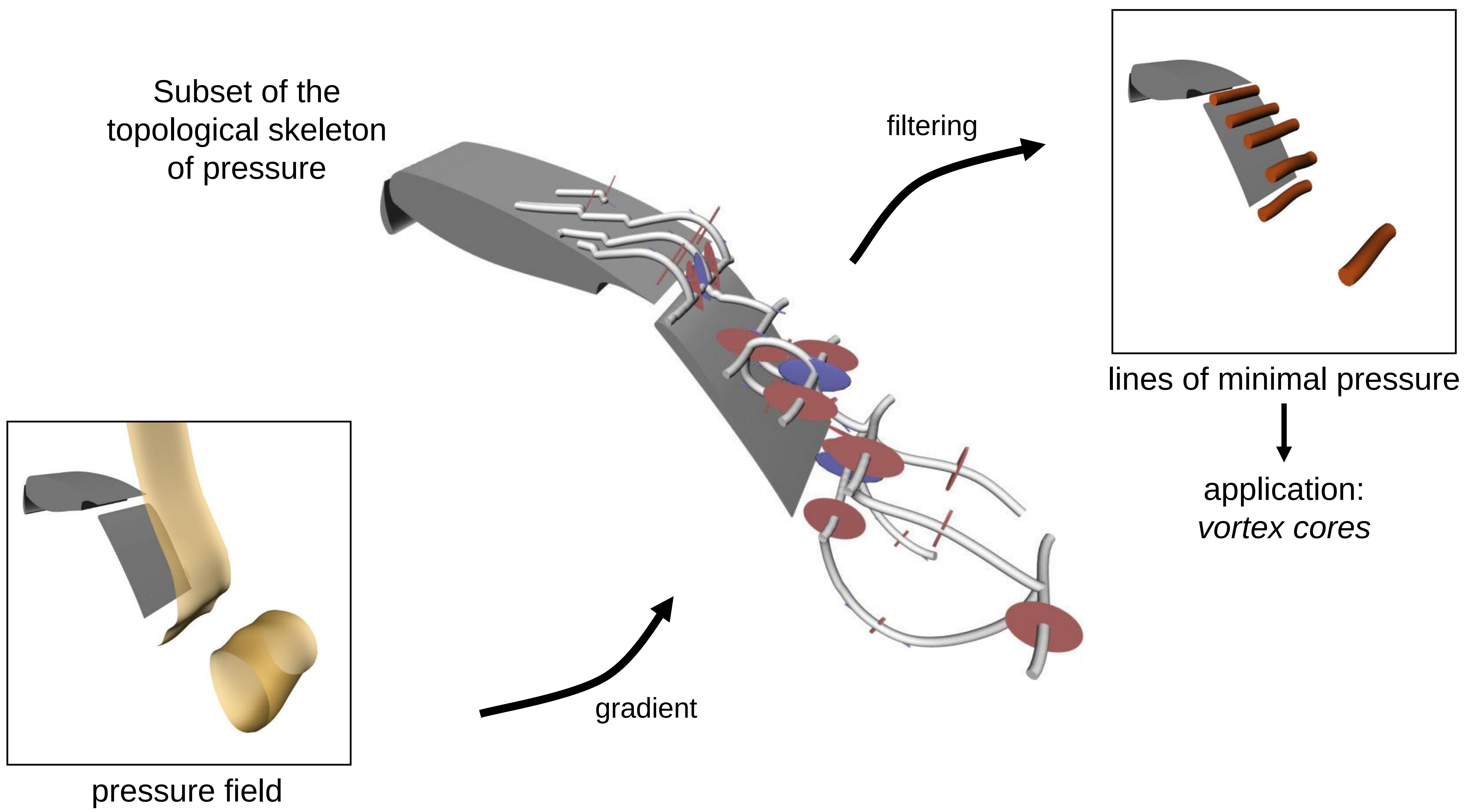


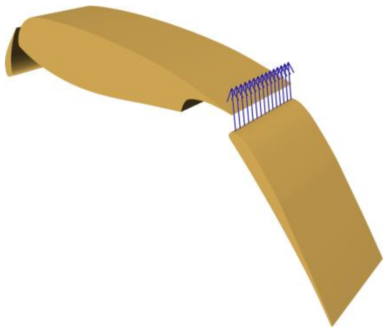
Parameters:

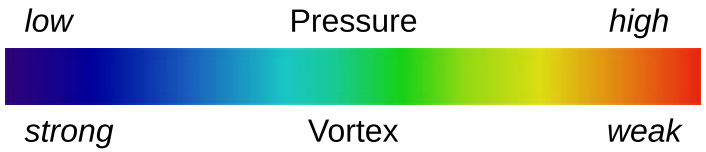
Frequency of air injection

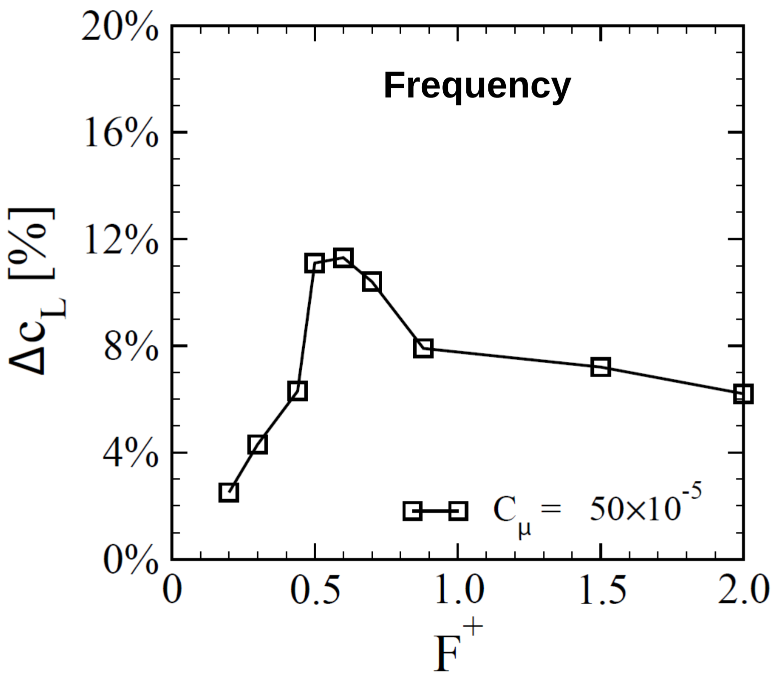
Intensity of air injection

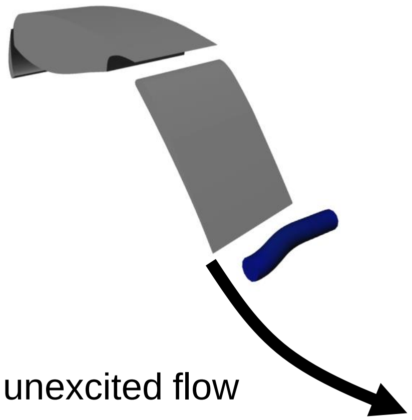
- 6 dimensional data set
- 23 parameter variations
- 3D flows with 200 time steps
- 1.3 million cells
- 200 GB data


Subset of the
topological skeleton
of pressure
filtering
lines of minimal pressure
application:
vortex cores
gradient
pressure field

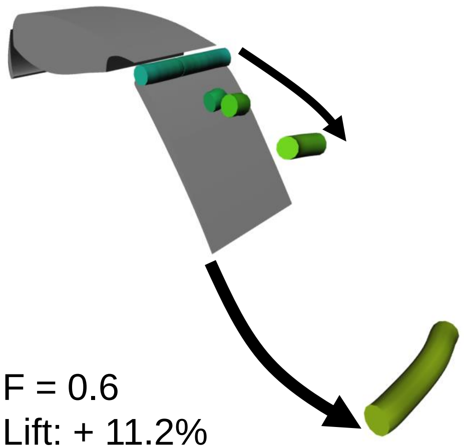




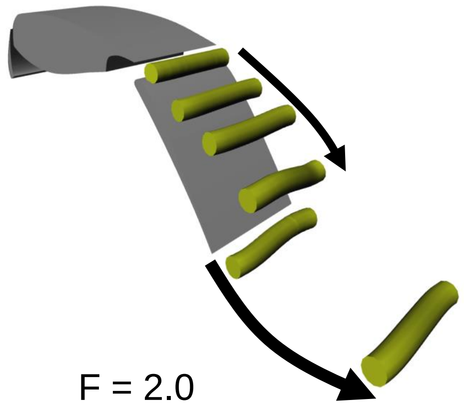




unexcited flow



F = 0.6
Lift: + 11.2%



F = 2.0
Lift: + 6.1%

Flow around an airfoil. Data courtesy of Bert Günther (TU Berlin).

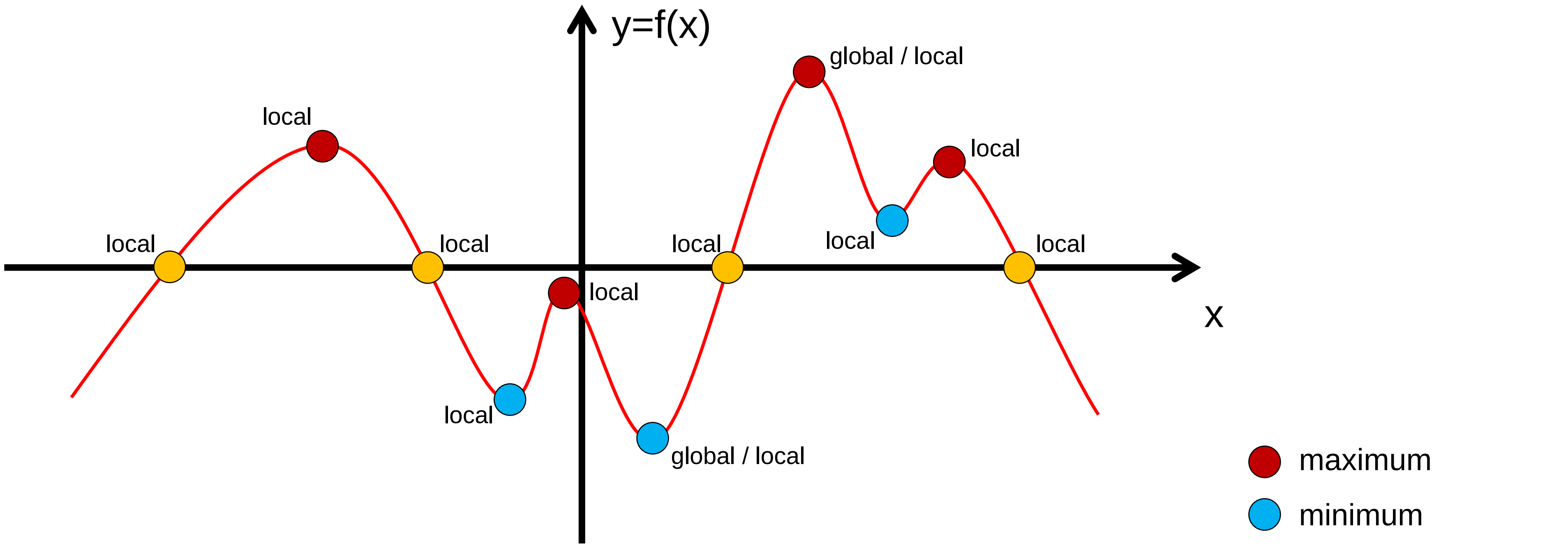
very important

Local Features

For every point:
decision by local analysis if it belongs to the feature

Global Features

Obtained by global analysis



very important

Local Features

- (Local) minima and maxima
- Roots (zero crossings)
- Ridge and valley lines/surfaces
- Cores of swirling motion
- Critical points
- Boundary switch points/curves
- Fold, Hopf bifurcations

Global Features

- Global minimum and maximum
- Separatrices
- Closed stream lines
- Saddle connectors
- Boundary switch connectors
- Topological segmentation (aka topological skeleton or Morse-Smale complex)
- Saddle connections (hetero-/homoclinic orbits)
- Watersheds / watercourses

Summary

- Feature-based visualization and data analysis methods
  - feature: geometric object in domain
- application-dependent definition and purpose
- theories and building blocks
  - topology
  - derivatives
- classic versus feature-based visualization
- local versus global features