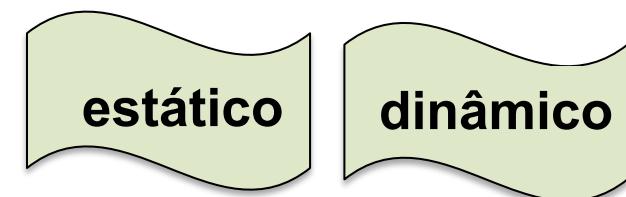
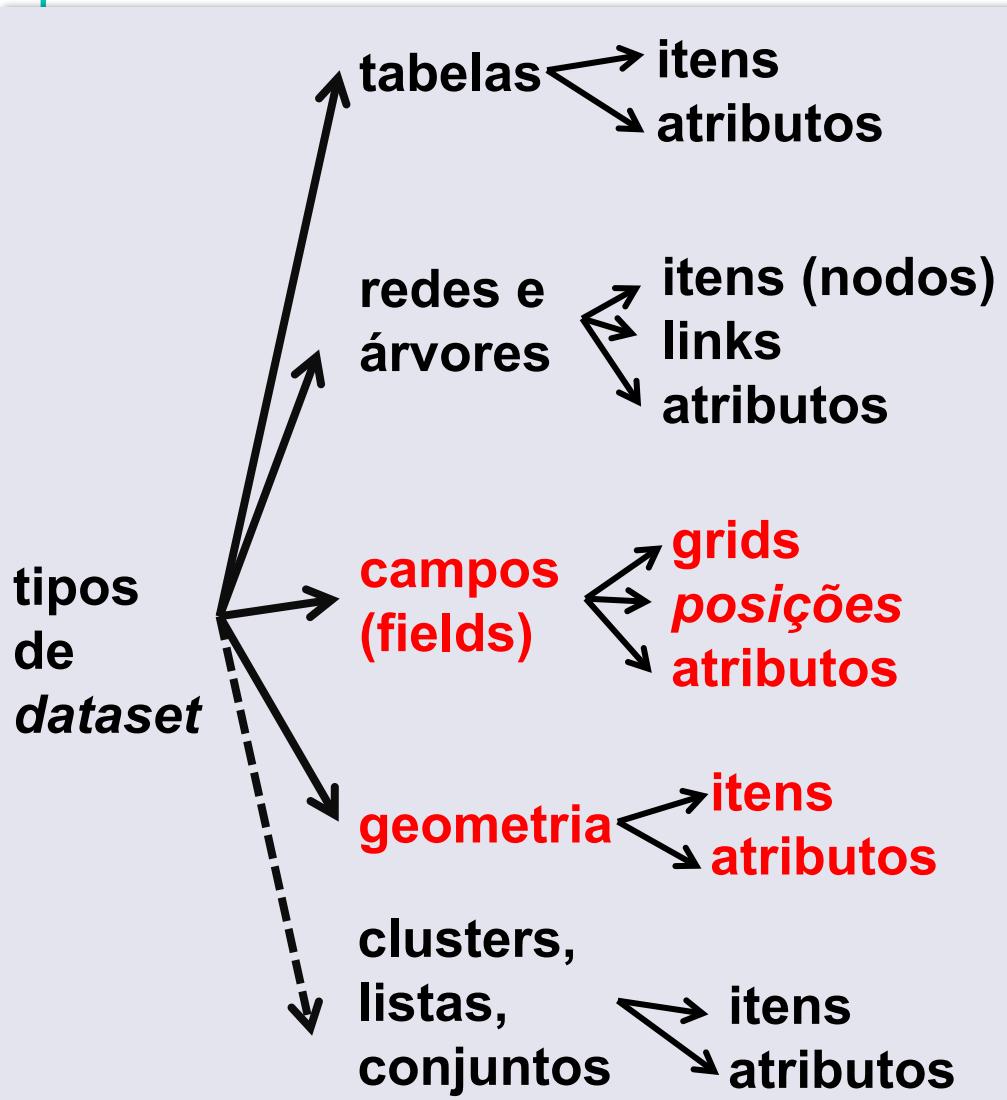


Visualization of Spatial Data

- Ward, M., Grinstein, G. and Keim, D.
 - Interactive Data Visualization (2010)
 - Chapter 5
- Flow visualization
 - Christoph Garth: An Introduction to Flow Visualization(2). IDAV/UCDavis

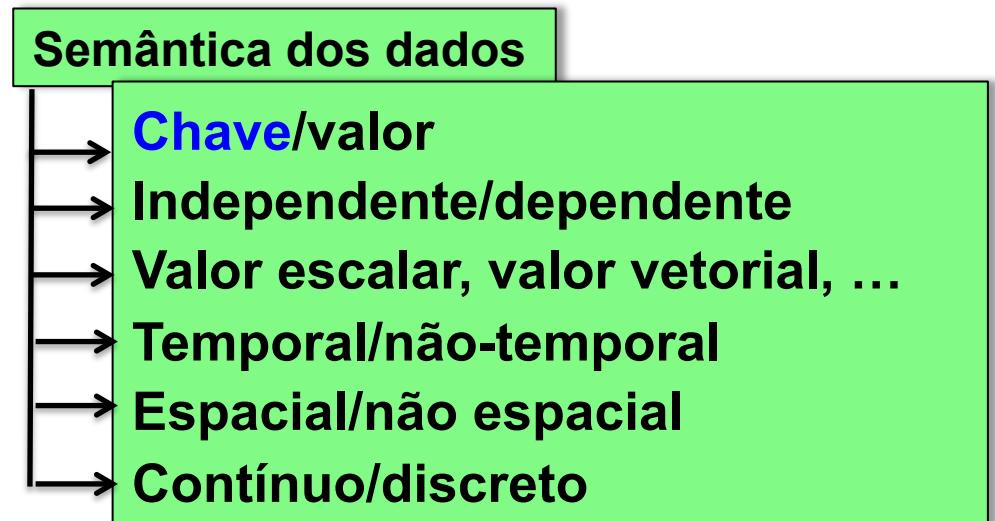
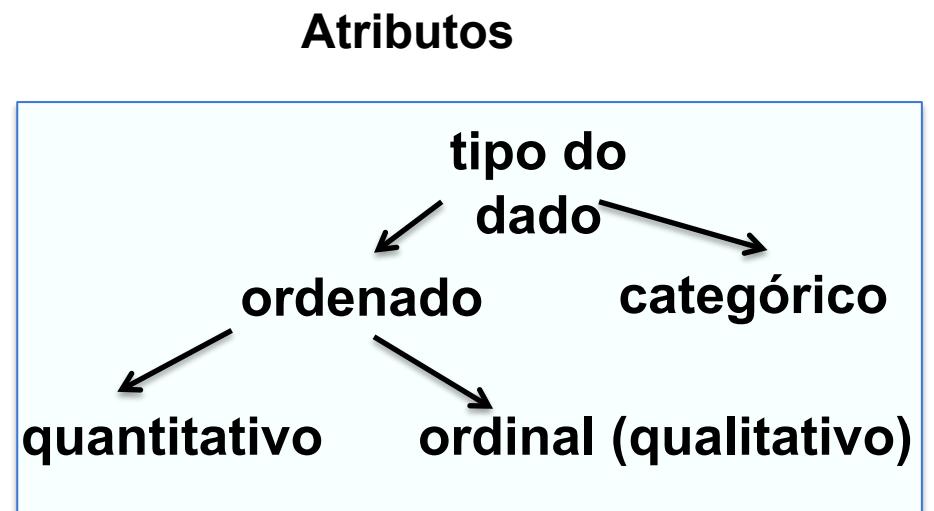
Caracterização de dados



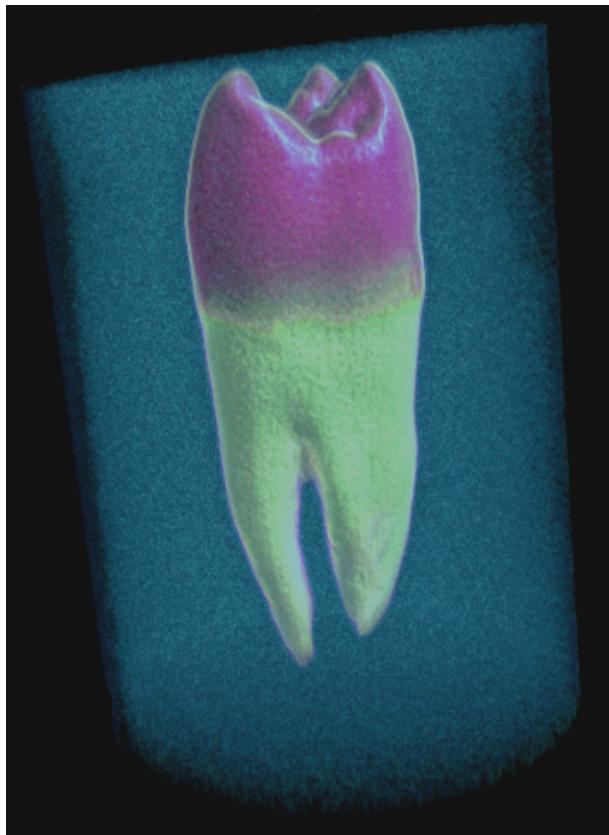
Munzner, Tamara *Visualization Analysis and Design*.
Boca Raton, FL:Taylor & Francis, 2014

Caracterização de dados

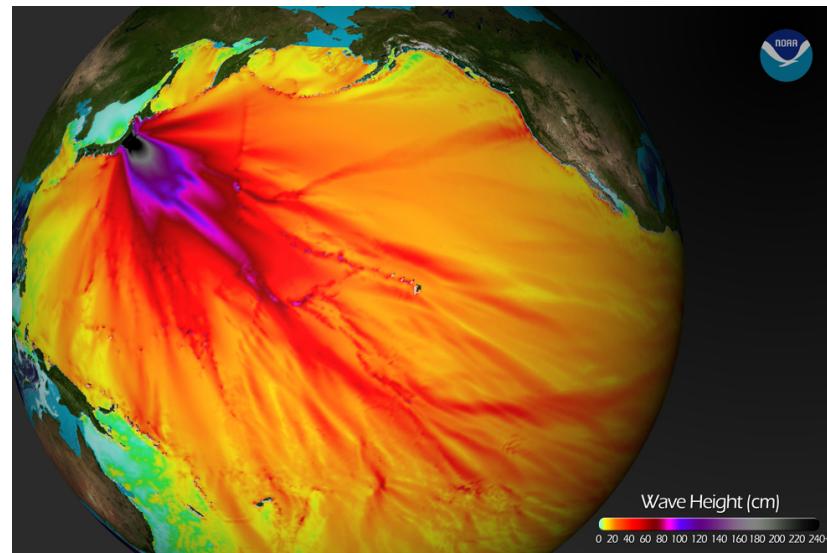
- Tipos de dados básicos
 - Item (nodo)
 - Atributo
 - Aresta
 - **Posição**
 - **Grid**



Characterization of Spatial Data

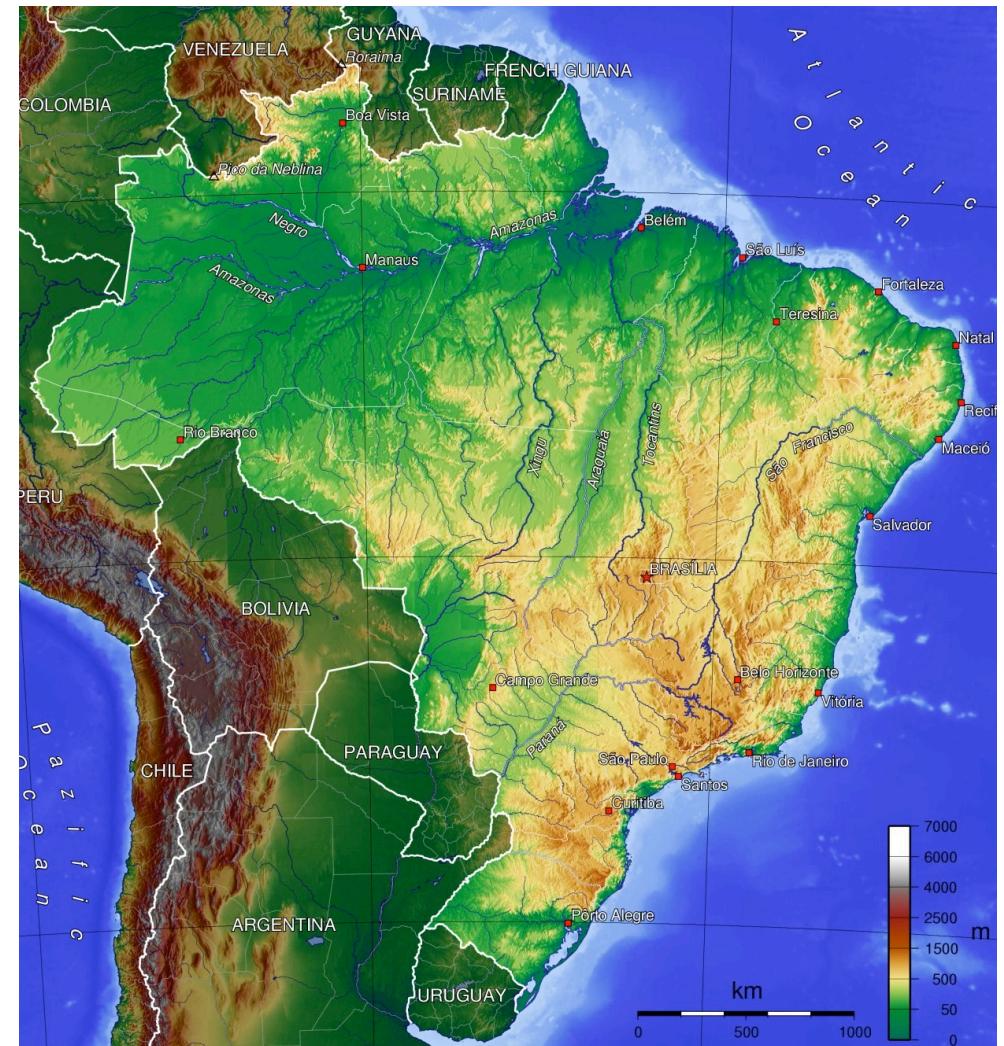


- Data has an implicit or explicit spatial or spatio-temporal attribute
 - Scientific data is usually associated to spatial or spatio-temporal positions



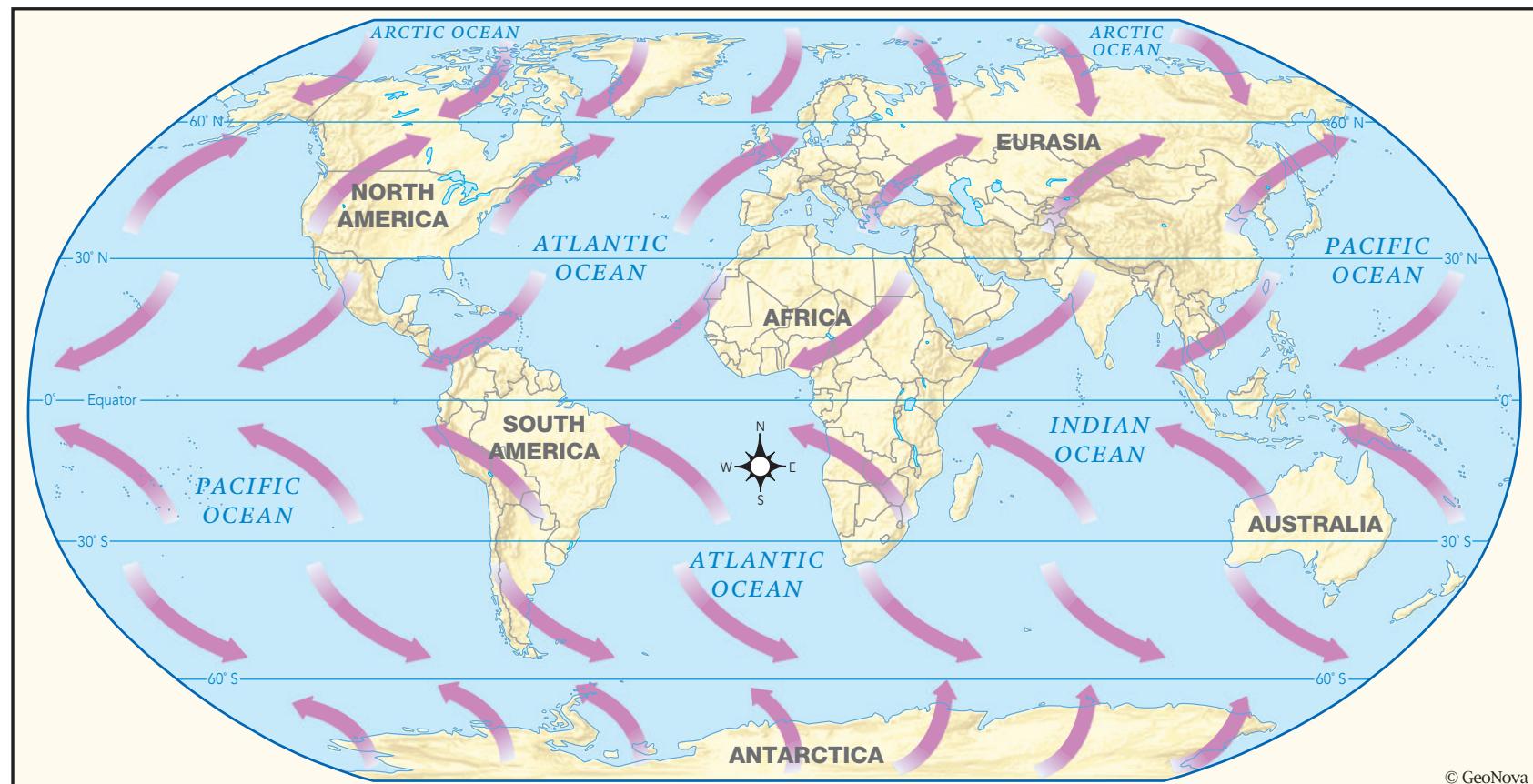
Characterization of Spatial Data

- Having a spatial attribute facilitates the creation and interpretation of the visualization
 - There is an intuitive, and often straightforward mapping of the data attributes to graphical attributes of the entities



Characterization of Spatial Data

- Our visual perception is used to observe physical phenomena associated to positions in space/time



© GeoNova

What's different in an interactive visualization on the screen?

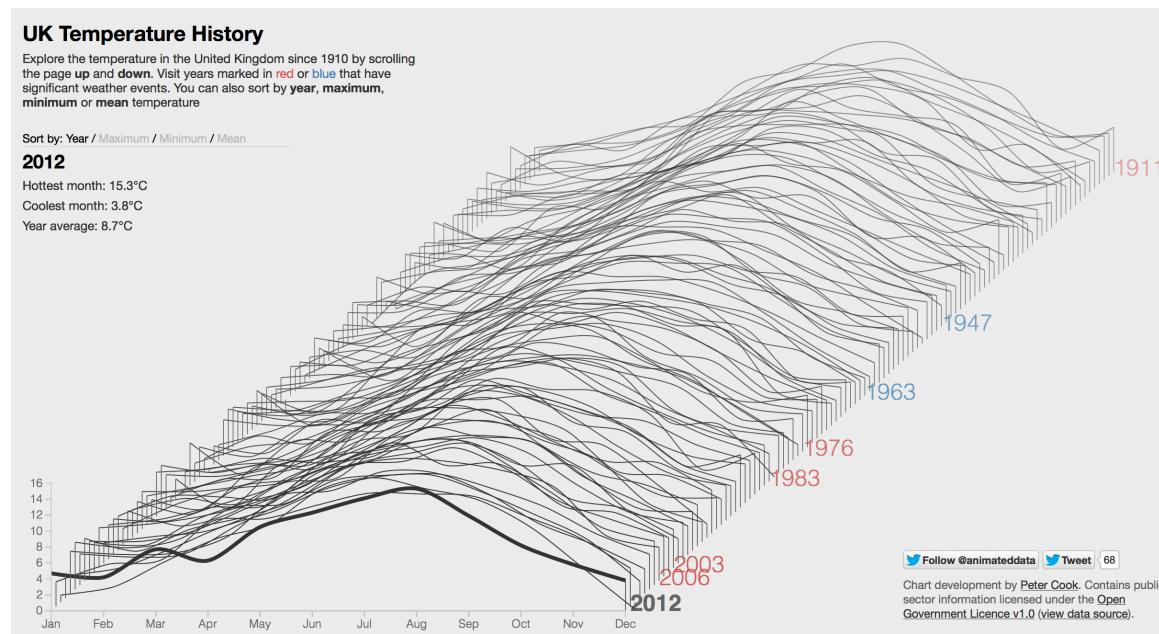
- We can visually explore real or simulated phenomena at arbitrary scales
- We can dynamically modify visual attributes (contrast, lighting, density, resolution, etc.)
- We can interactively navigate spaces that would be hard to enter in real life
- We can interactively add and remove parts of the data to get more context or remove clutter

Main problem

- We must decide which spatial attributes of the data will map to the spatial attributes (locations) on the screen
 - May involve transformations, scaling, rotation, translation, shearing, projection
- Other data attributes will be mapped to other components of the visualization
 - Color or textures
 - Size or shape of a graphical entity

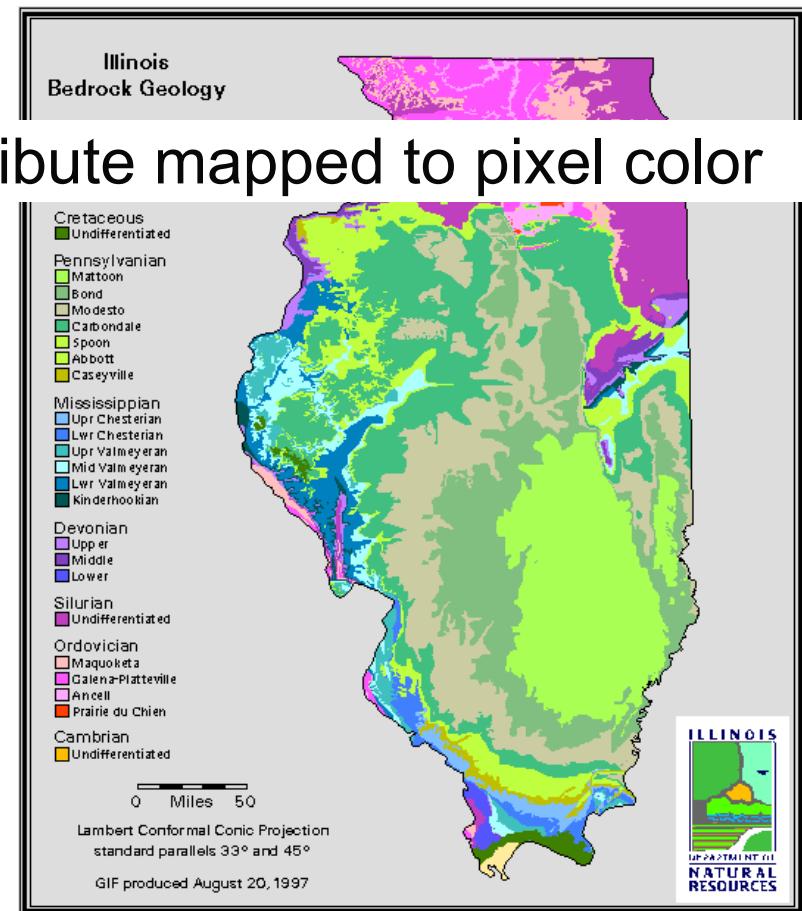
One-dimensional data

- Results of the accumulation of samples along a path in space
 - spatial locations (distances) taken from an origin
 - time period in a specific position in space
 - one dimensional sequence of univariate or multivariate data



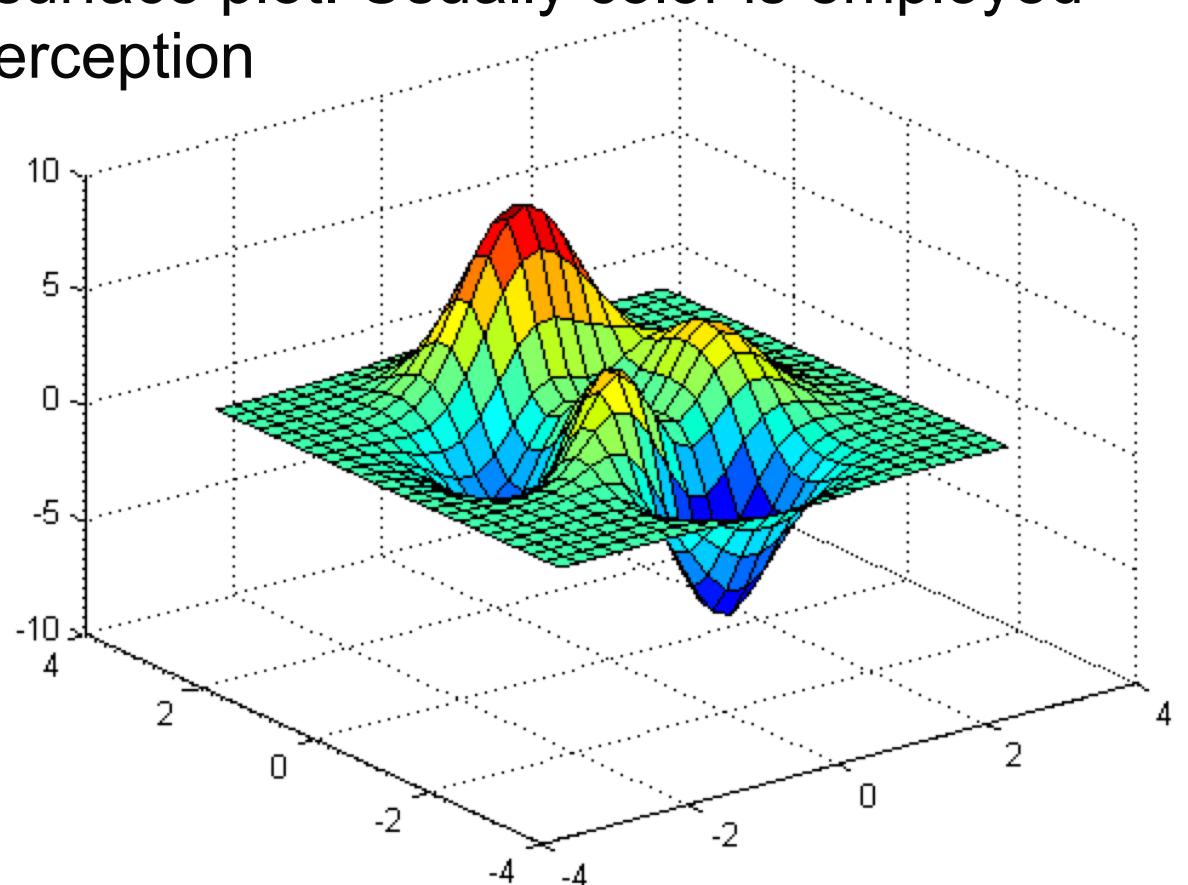
Two-dimensional data

- It is natural to map the spatial attributes of the data to spatial attributes of the image of the screen
- Possible visualizations:
 1. Image: scalar/categorical attribute mapped to pixel color



Two-dimensional data

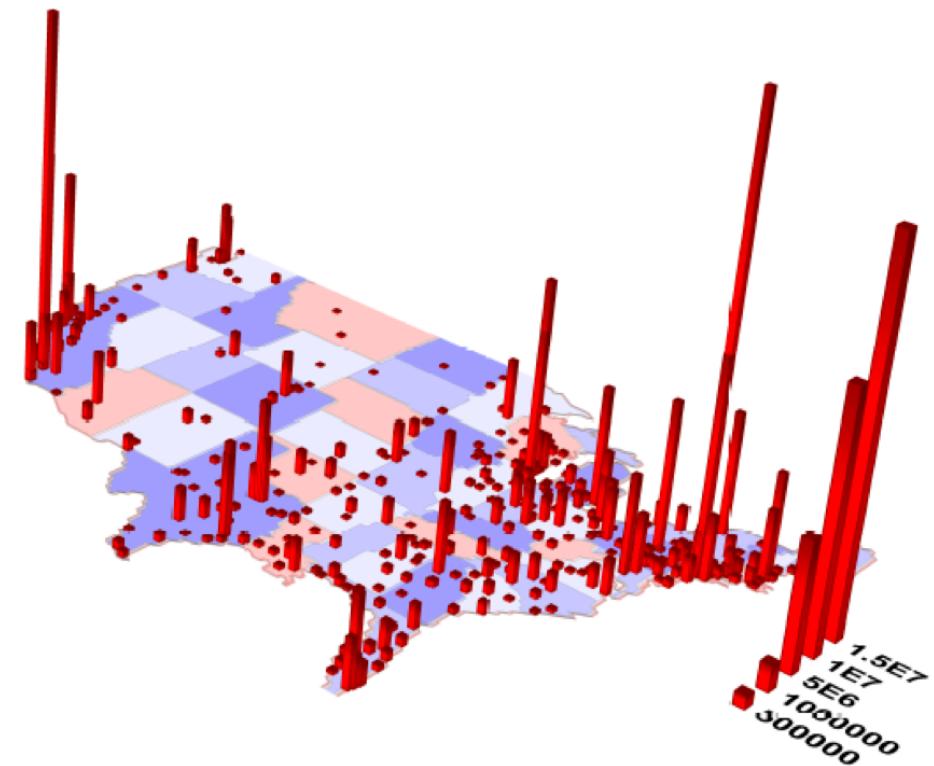
- Possible visualizations:
 2. Height map: scalar attribute mapped to the height of a point forming a 3D surface plot. Usually color is employed to enhance value perception



Two-dimensional data

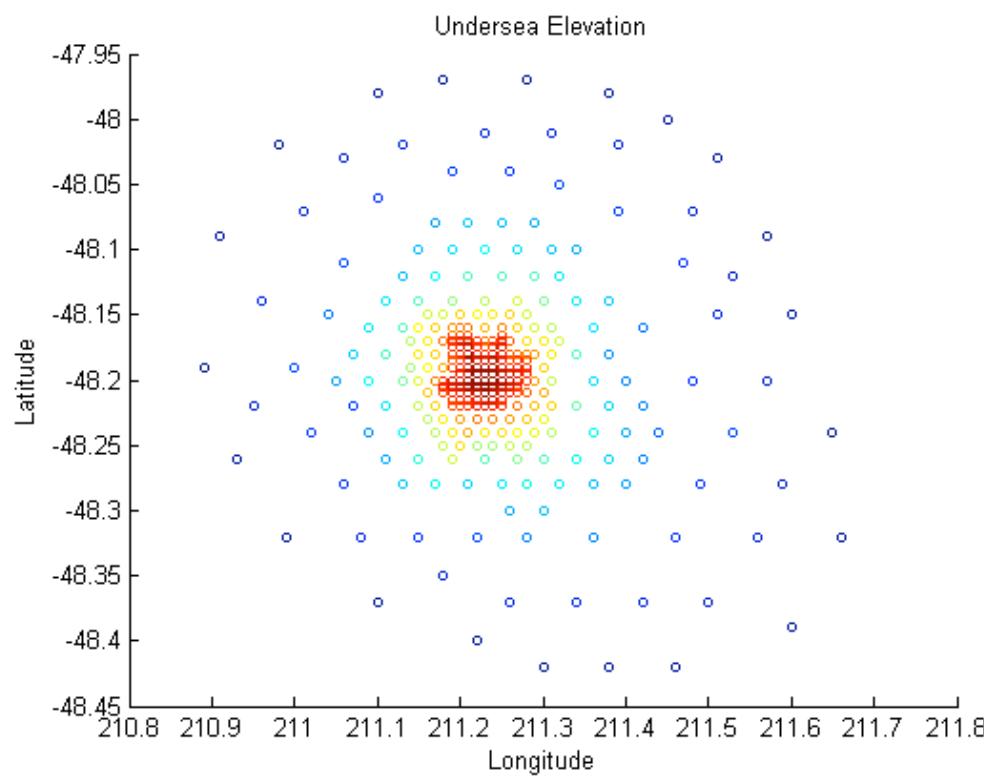
- Possible visualizations:
 3. Cityscape: data attributes mapped to 3D objects at locations on a plane

US Metropolitan Population Distribution



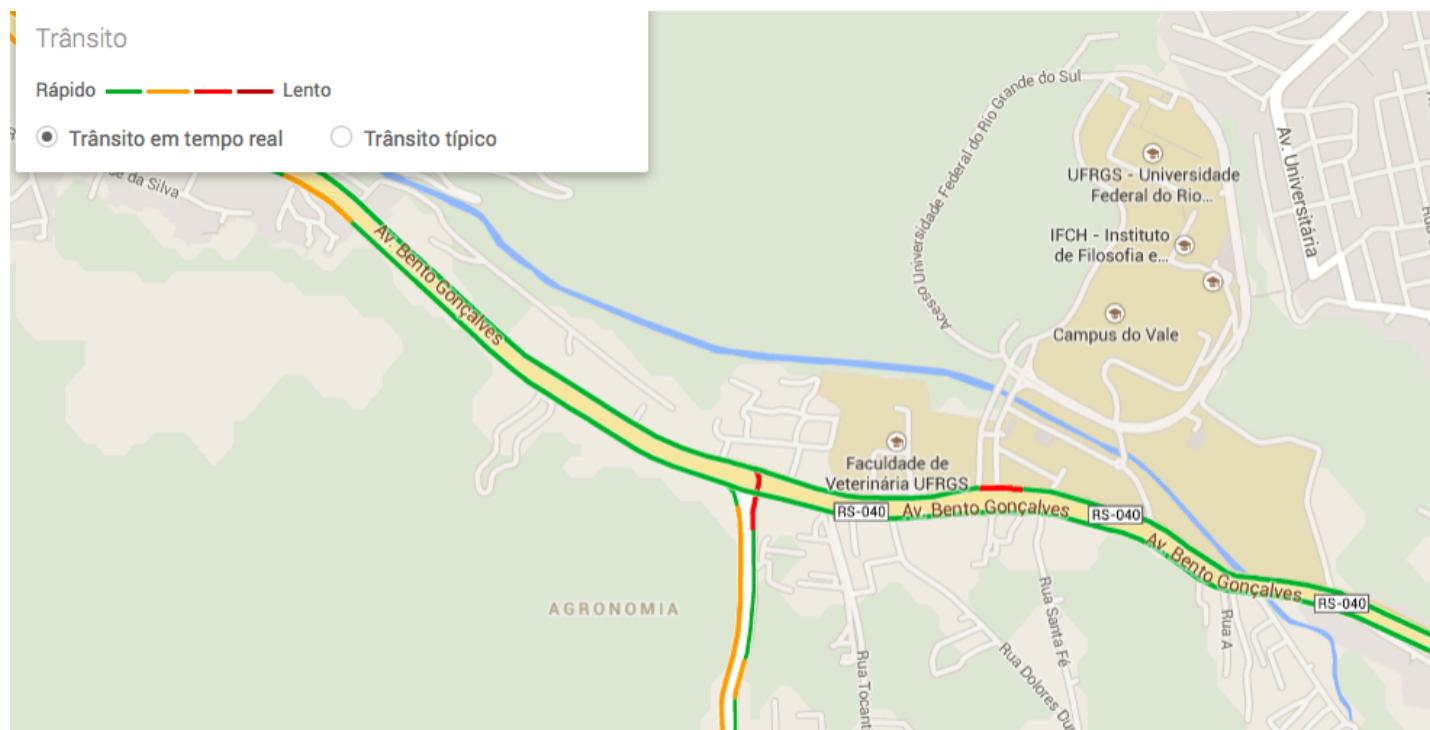
Two-dimensional data

- Possible visualizations:
 4. Scatterplot: at each location, values of data attributes control the size, shape or color of a marker



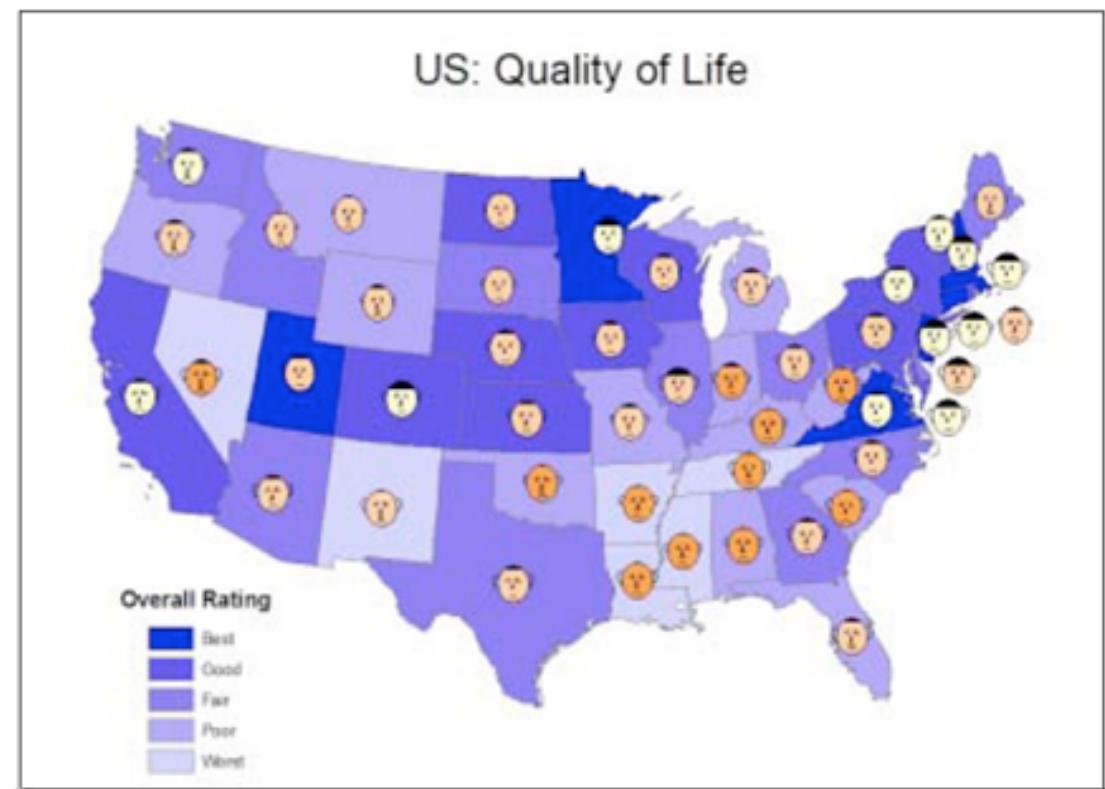
Two-dimensional data

- Possible visualizations:
 5. Map: data contains linear and area features, as well as point objects.



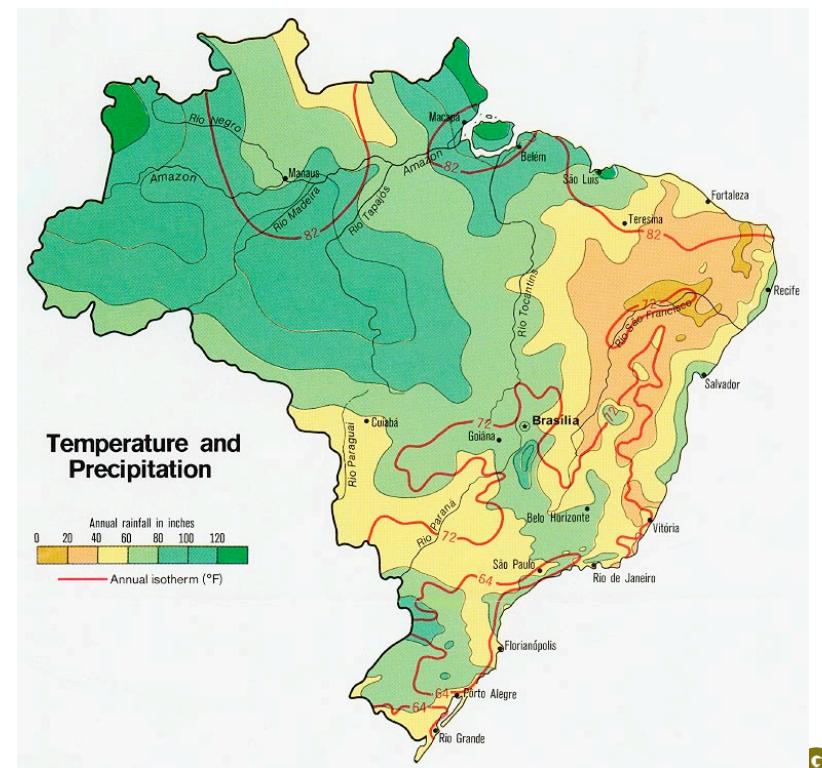
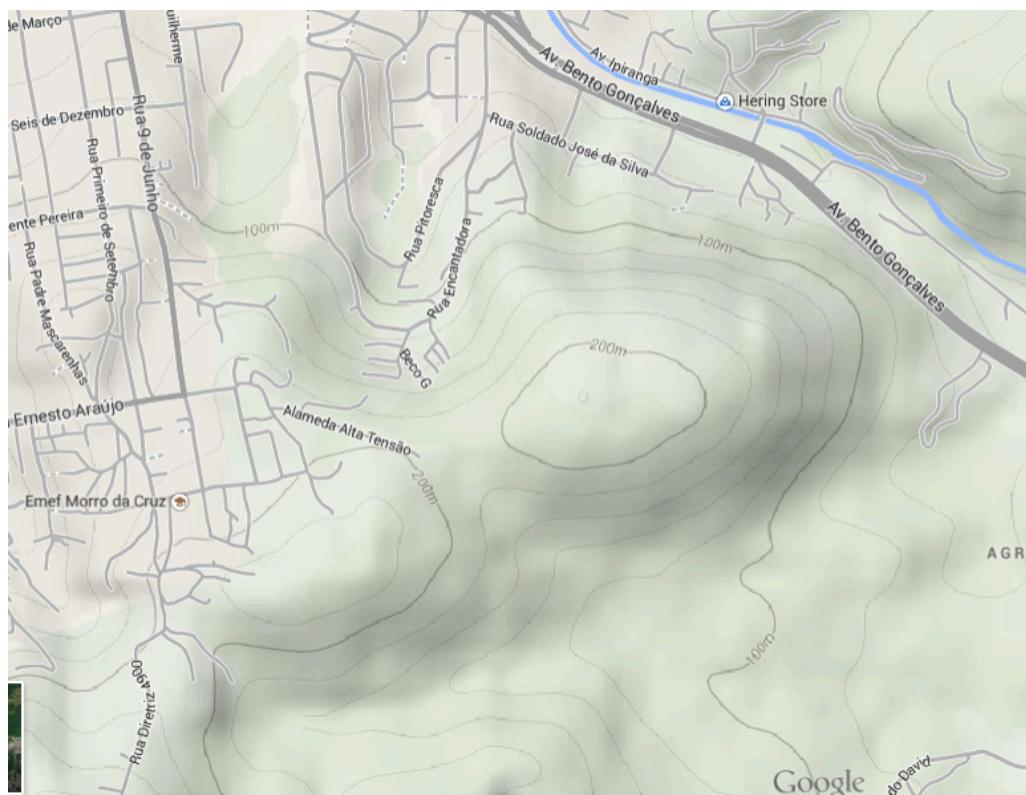
Two-dimensional data

- Possible visualizations:
 5. Map: data contains linear and area features, as well as point objects.



Two-dimensional data

- Possible visualizations:
 6. Contour or isovalue map: corresponds to binary information extracted from an image/scalar field which depicts a continuous phenomena

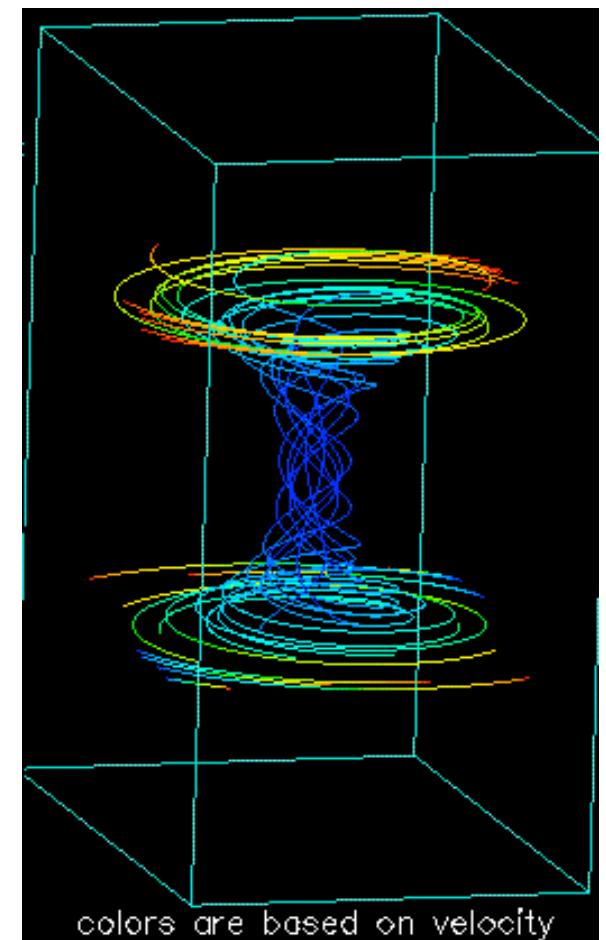


Probing 2D Data

- Besides visualizing 2D data, the user might want to visualize 1D subsets, projections or summarizations of the data
 - **Frequency histograms** of specific values or ranges of values (bar graphs)
 - **Row and columns aggregations**: sums, averages, standard deviation, minimum and maximum values (color bars, bar graphs, line plots)
 - **Linear probes**: it's a line passing through the 2D grid and along which we calculate the data values. The linear probe is created using a parametric equation and the data values are obtained using bilinear interpolation.

Three-dimensional data

- Discrete samples from a continuous domain
- Values associated to a structure described by vertices, edges and polygons
- Combination of both approaches



Three-dimensional data

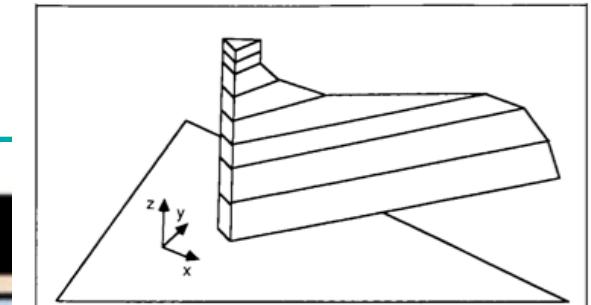
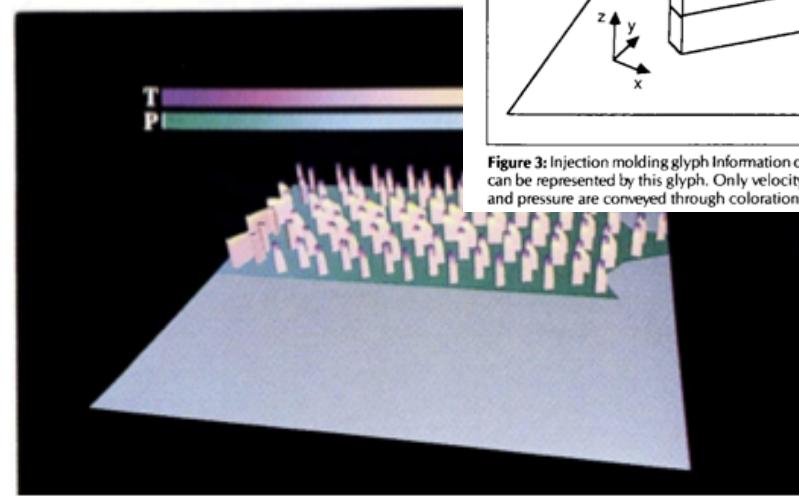
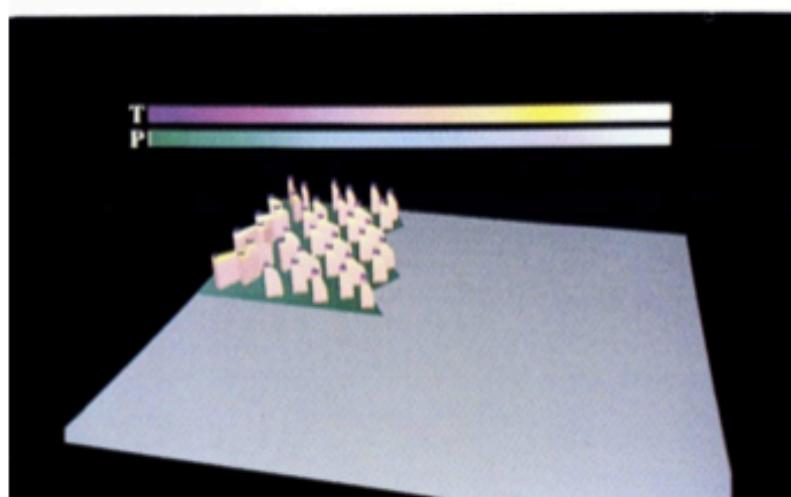
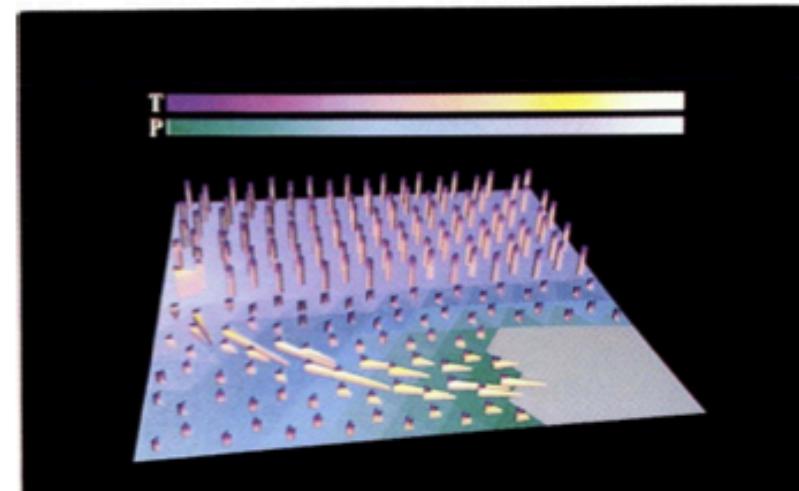
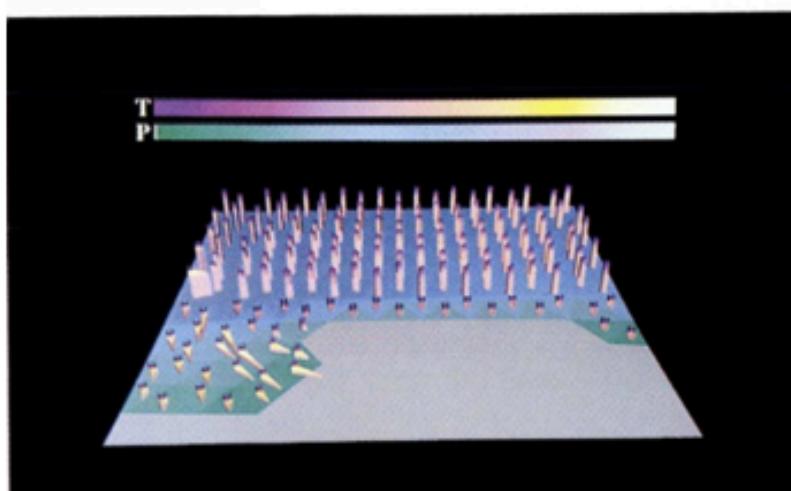


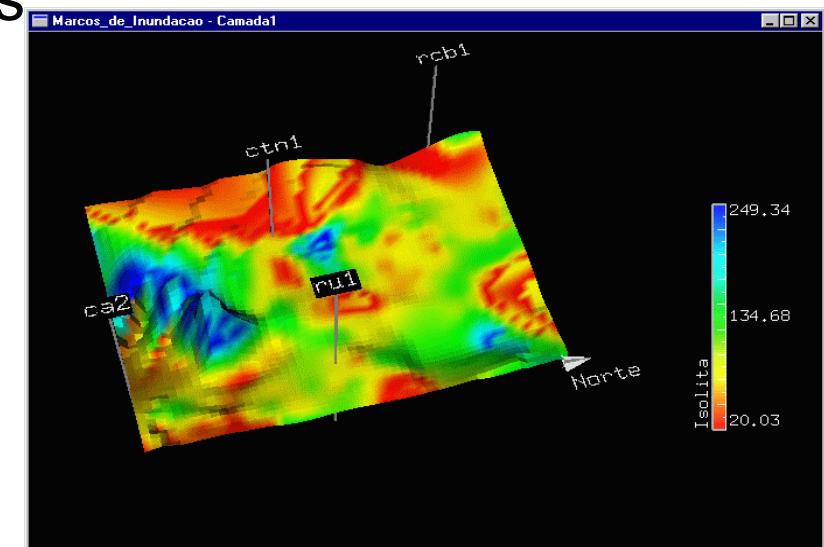
Figure 3: Injection molding glyph. Information on pressure, temperature and velocity can be represented by this glyph. Only velocity is shown here as both temperature and pressure are conveyed through coloration of the glyph structure.



Ellson, R.; Cox, D. Visualization of injection molding. Simulation, 1988, 51:184-188

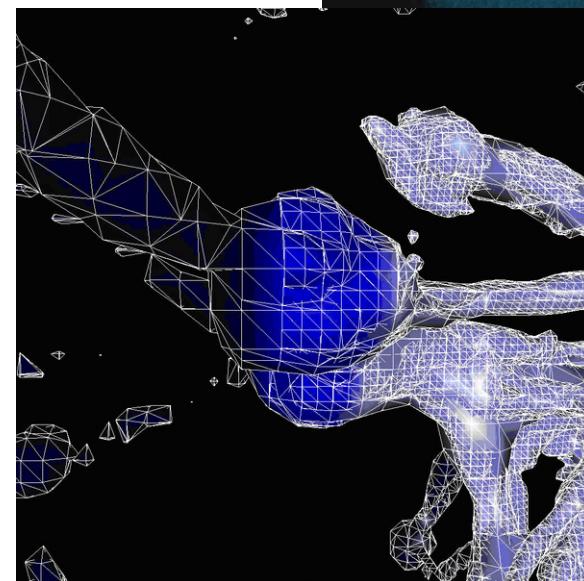
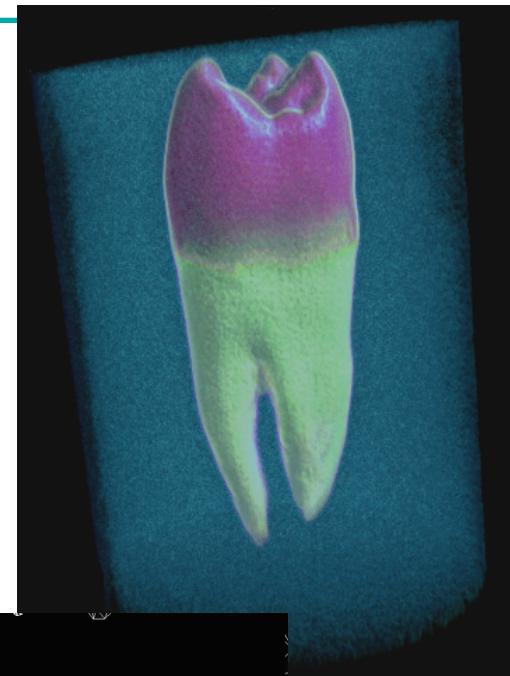
Three-dimensional data

- Data associated to a surface
 - Surface may be a polygon mesh, a parametric surface or an implicit surface (usually approximating a cloud of points)
 - Data may be associated to vertices
 - Temperature or stress in a joint
 - To edges
 - Strength of attraction for a chemical bond
 - To faces/surface patches
 - Ground cover for a region
- Usually visualized through mapping values to color, texture, opacity, symbol, depending on the attribute



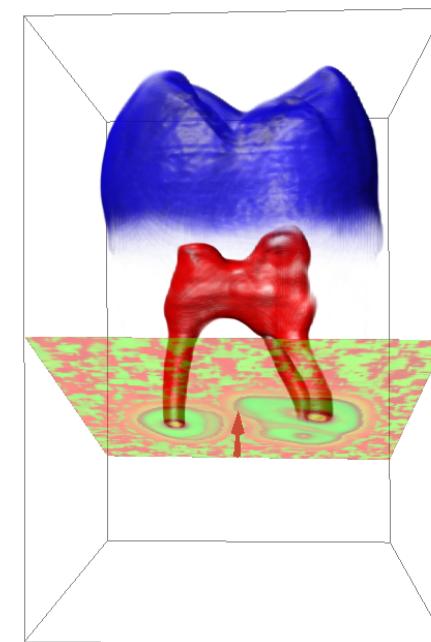
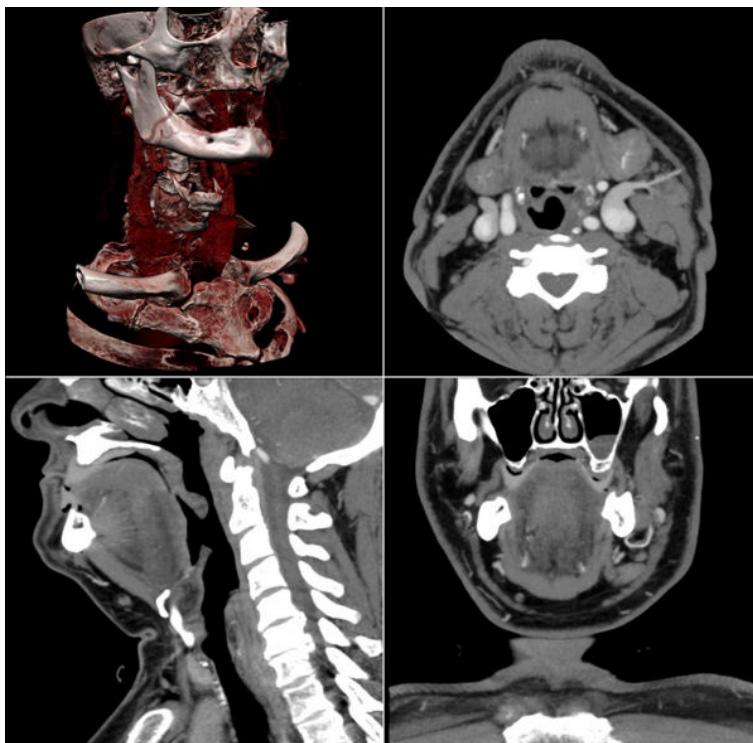
Three-dimensional data

- Data associated to a surface
 - Surface may be a polygon mesh, a parametric surface or an implicit surface (usually approximating a cloud of points)
- Data associated to volume cells
 - Voxels in a cartesian/regular grid
 - Cells in a unstructured grid



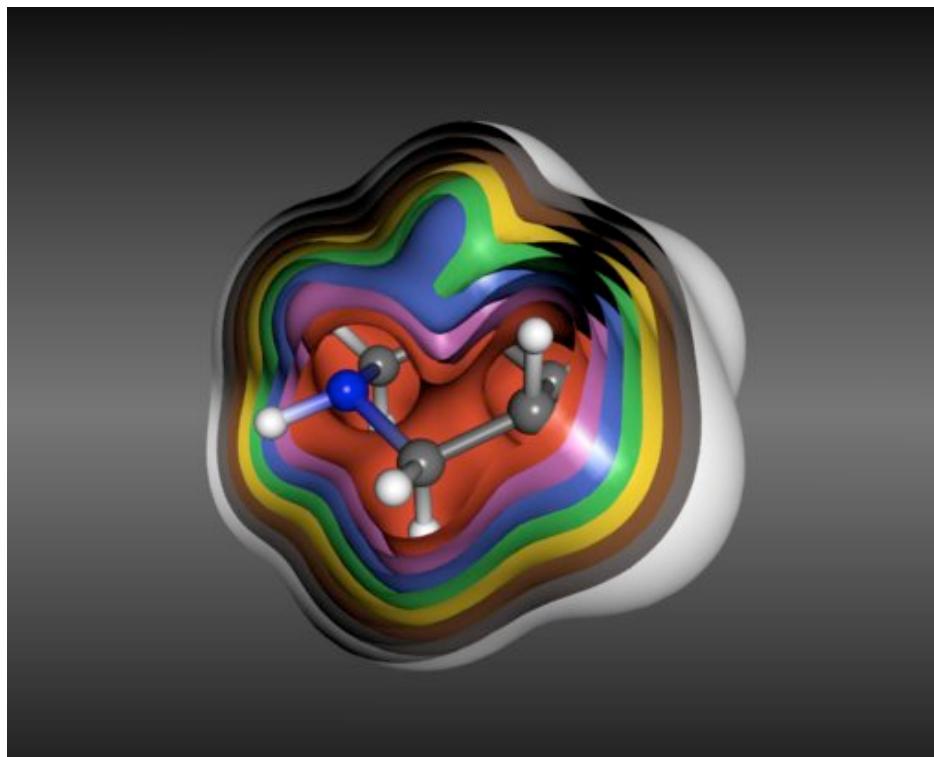
Three-dimensional data

- Categories of volume visualization techniques
 - Slicing techniques
 - User inspects the volume using a cutting plane



Three-dimensional data

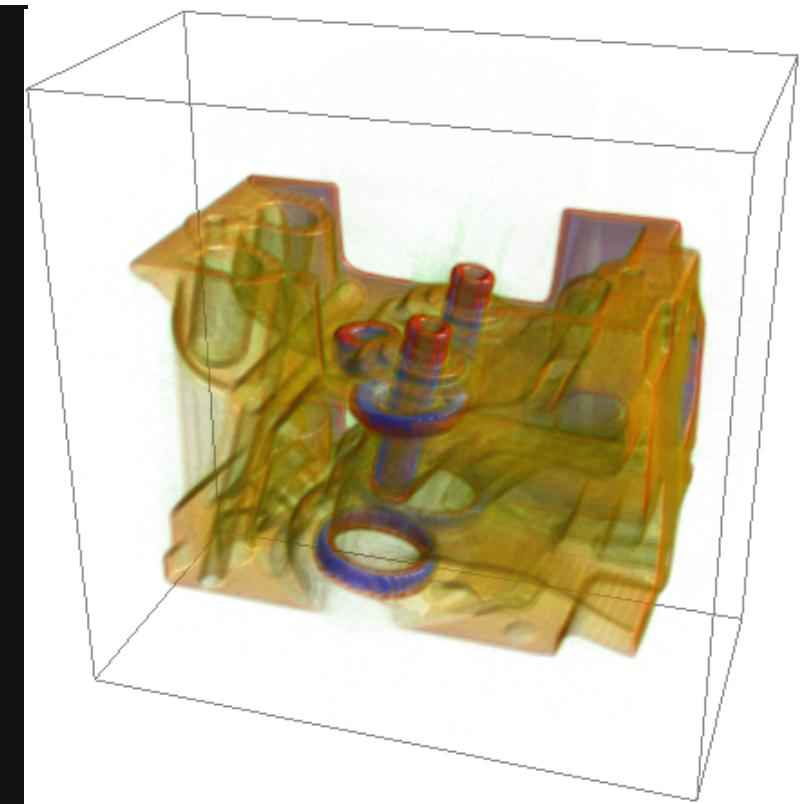
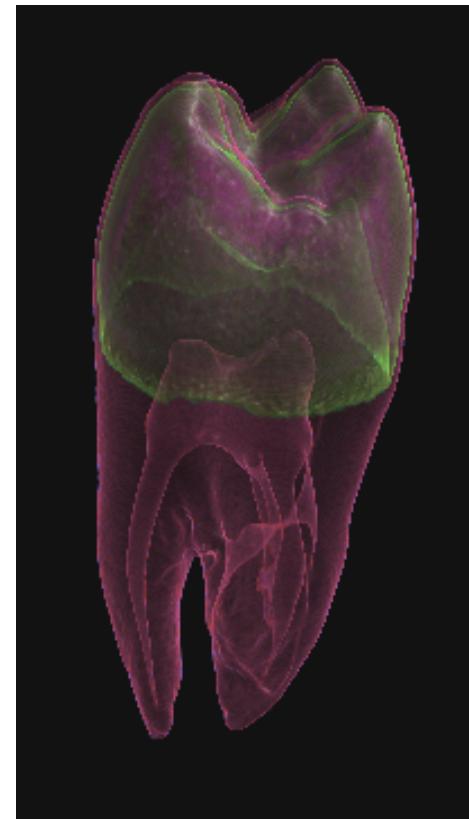
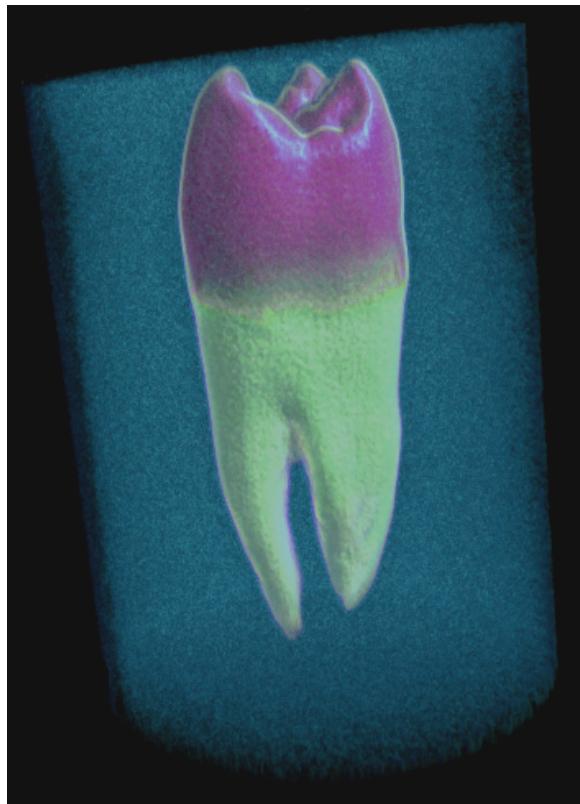
- Categories of volume visualization techniques
 - Isosurface techniques



**Different electron density
isosurfaces of piperidine.
Isosurfaces can be
calculated and displayed
from 3D data contour files.**

Three-dimensional data

- Categories of volume visualization techniques
 - Direct volume rendering

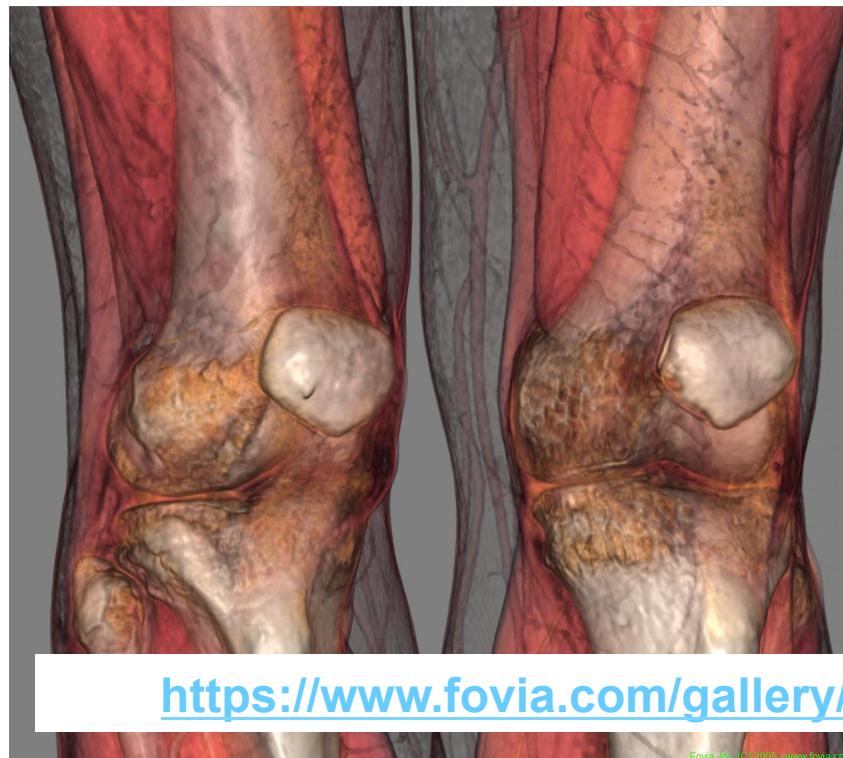


Examples

Videos

- Transfer functions
- Importance-aware rendering

Website:

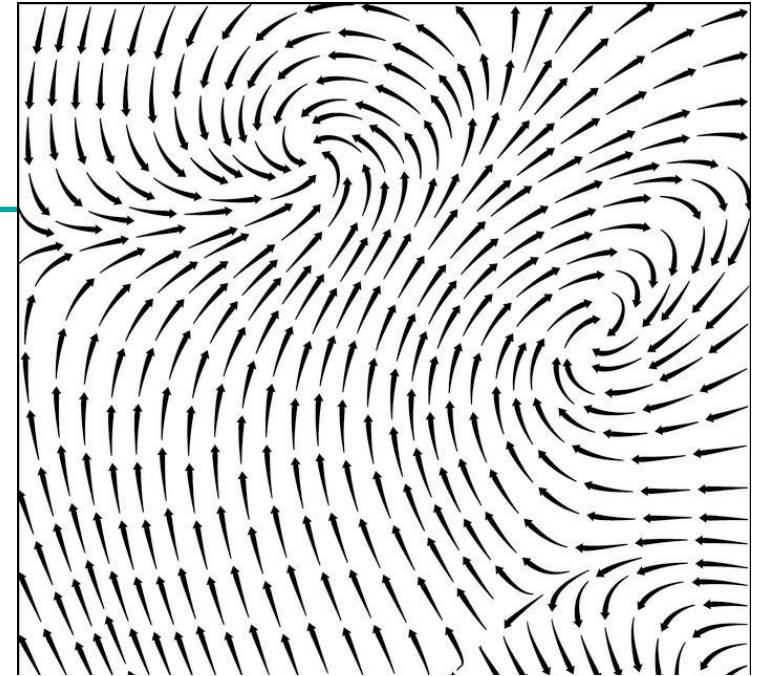


Visualization of Spatial Data

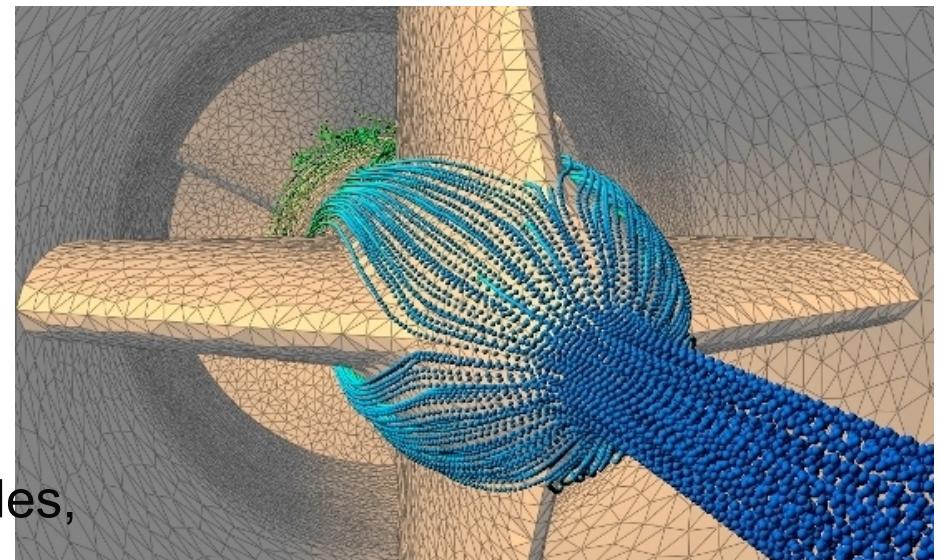
- Ward, M., Grinstein, G. and Keim, D.
 - Interactive Data Visualization (2010)
 - Chapter 5
- Flow visualization
 - Christoph Garth: An Introduction to Flow Visualization(2). IDAV/UCDavis

Dynamic data

- 2D or 3D grids with vectors
 - Vector fields
 - Usually velocity fields
- Static field
 - One single, unchanging vector field (steady flow)
- Time-varying field
 - The values of the vector field change
 - The positions and the values change (unsteady flows)
 - Ex.: model of rotating turbine blades, pitching airfoils

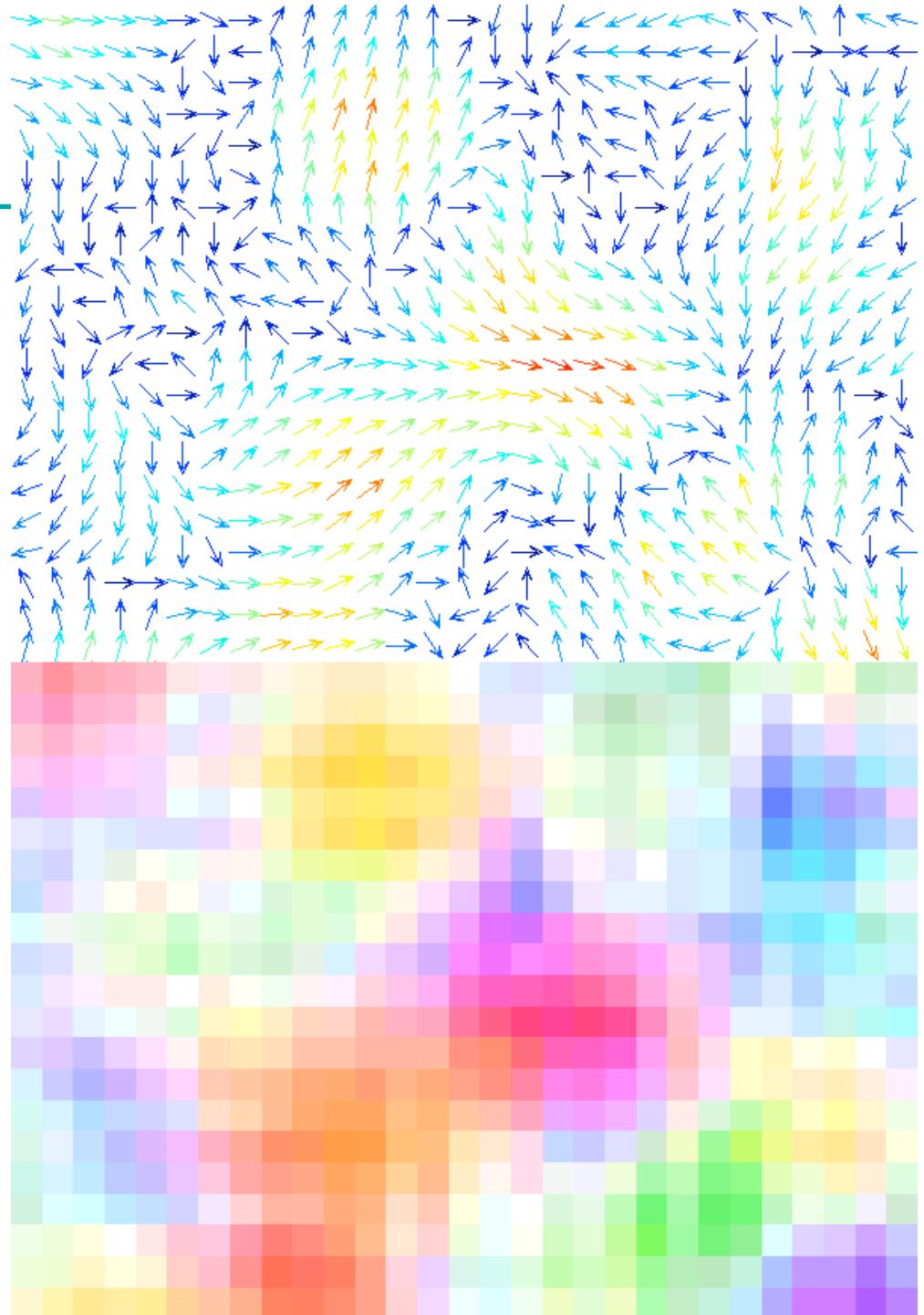


Laidlaw and Kirby (2001). Quantitative Comparative Evaluation of 2D Vector Field Visualization Methods.



Flow visualization

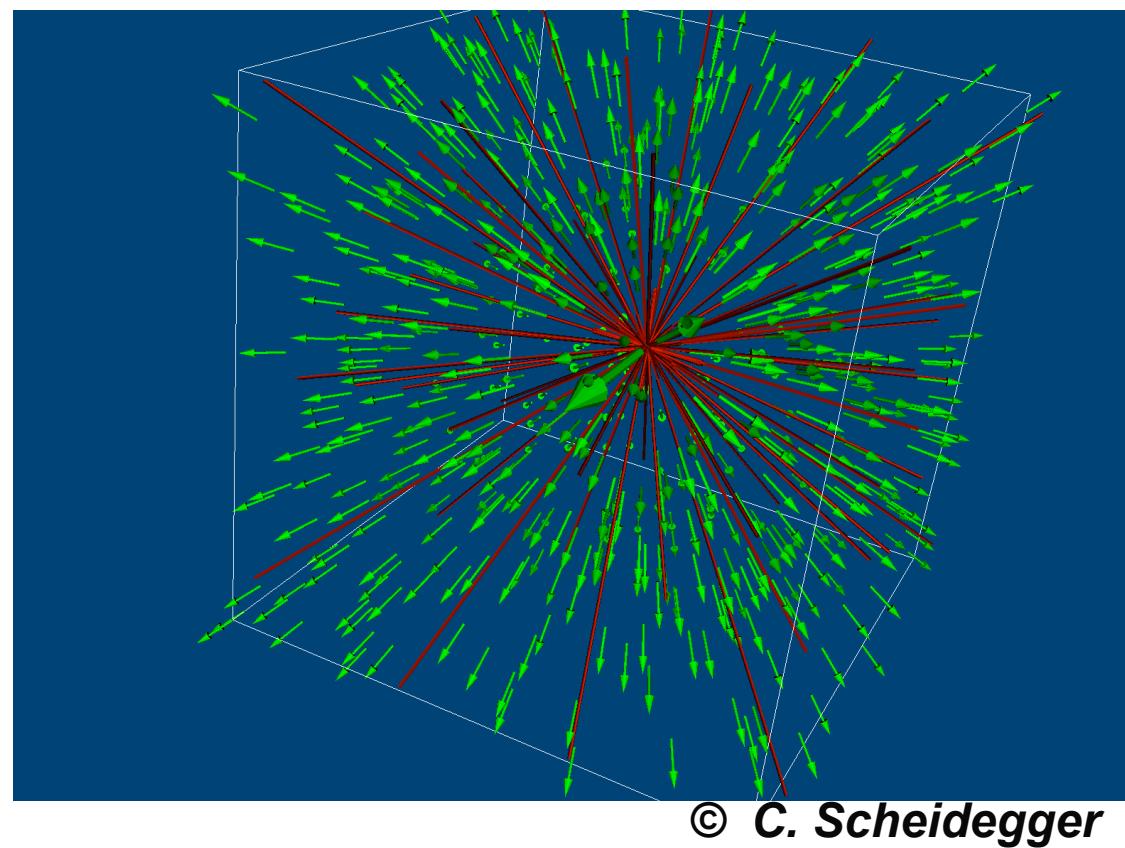
- Visualization of the vector field itself
 - Displacement vectors
 - Magnitude (scalar) values (usually color or size)



<http://www.mathworks.com/matlabcentral/fileexchange/29487-2d-vector-field-visualization>

Flow visualization

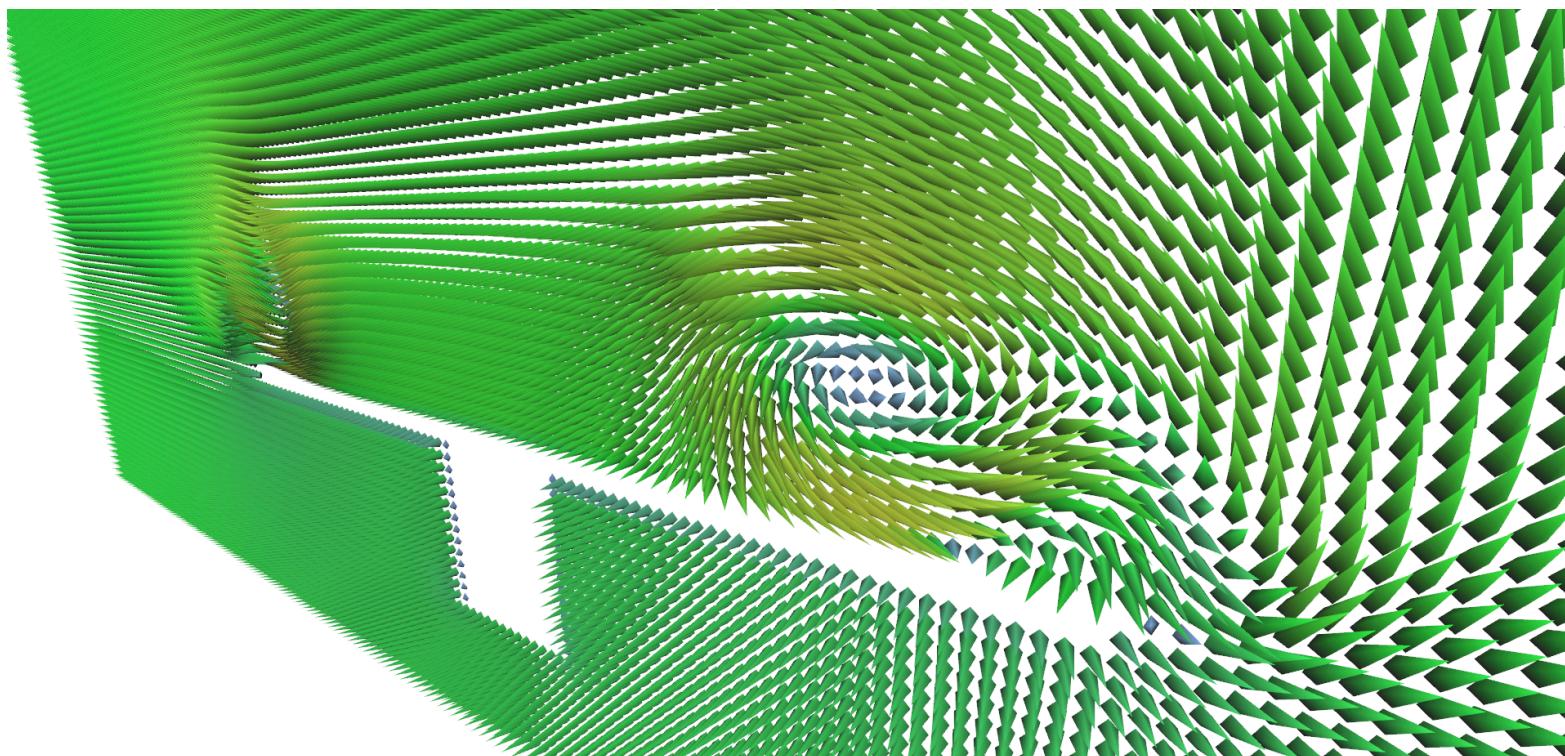
- Visualization of the vector field itself
 - Displacement vectors (colors denote vector magnitude)



© C. Scheidegger

Flow visualization

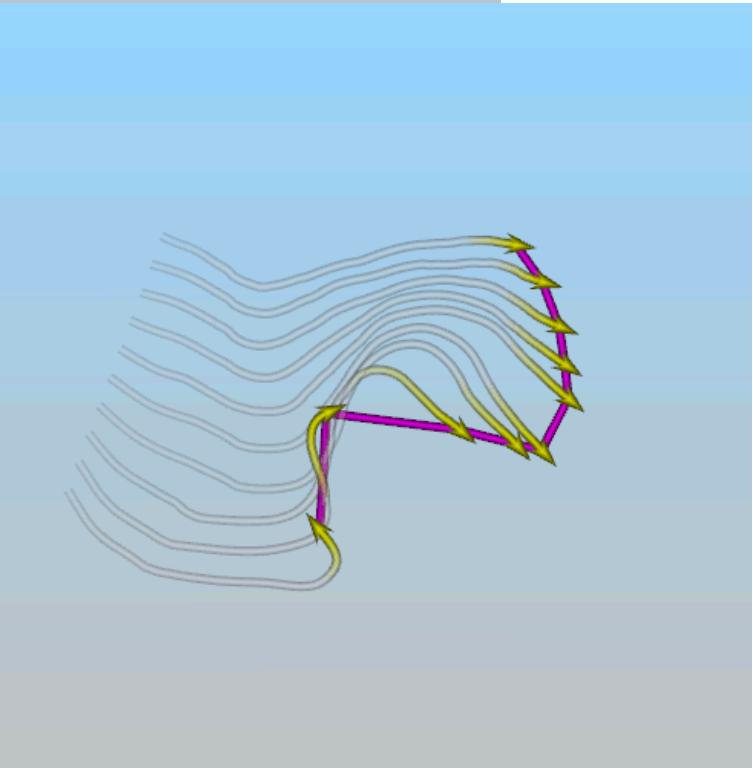
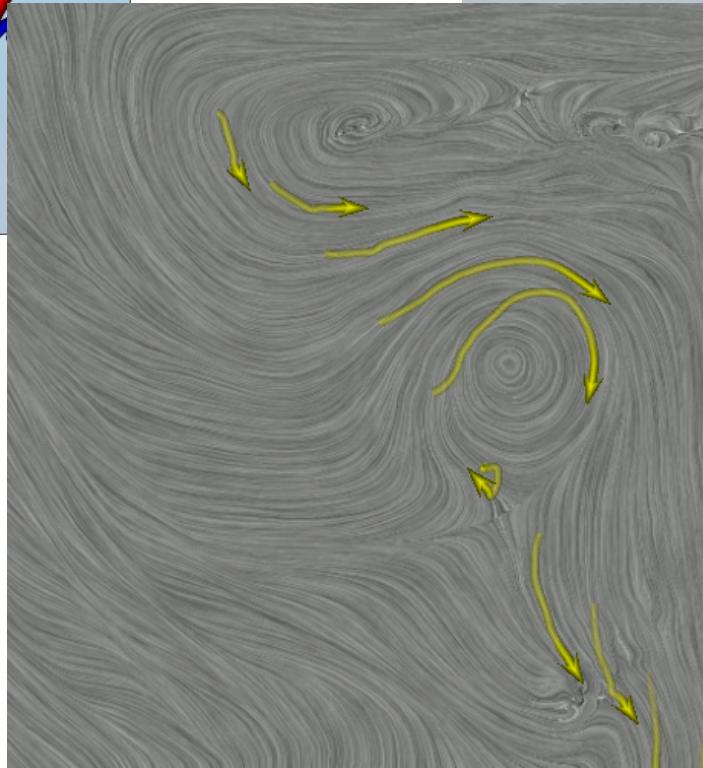
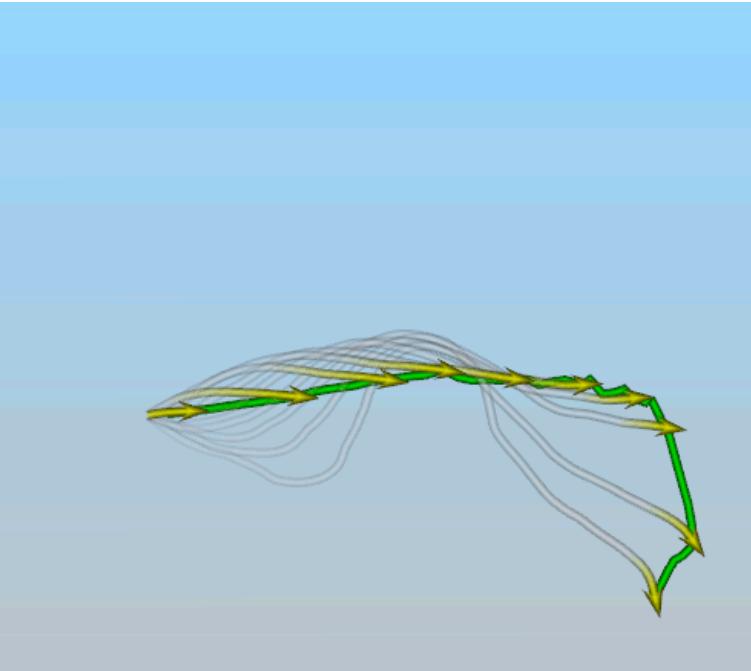
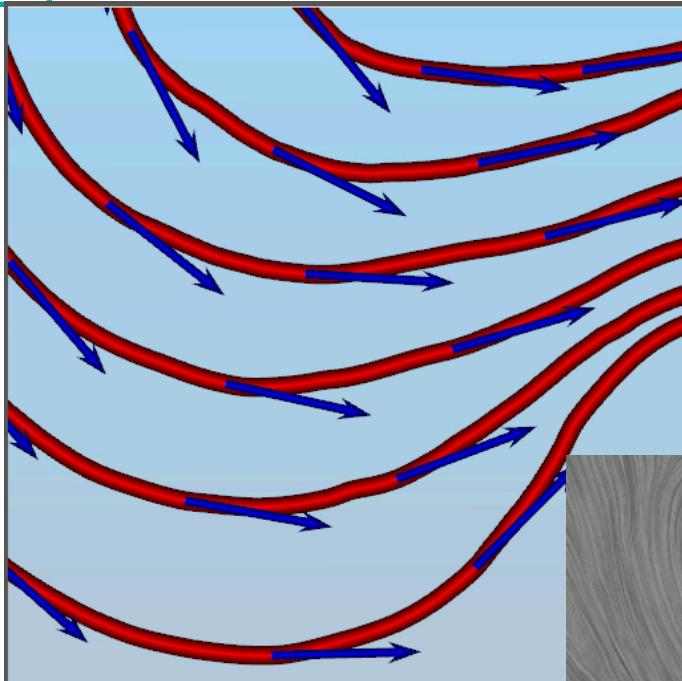
- Visualization of the vector field itself
 - Displacement glyphs



<http://www.marekfiser.com/Projects/Vector-field-visualization-on-GPU-using-CUDA/3-Visualization-using-glyphs>

© 2014 Marek Fišer

Other techniques ...



Flow visualization: streamlines

- **Streamlines** based on a steady (constant) velocity field
 - Lines through the velocity field that are tangent to the vector field at every point
 - The user selects seed locations and, for each seed, a path is traced through the field, maintaining a continuous tangent to the flow field. These show the direction a fluid element will travel to at any point in time.
 - **Pathlines** are identical to streamlines in steady vector fields
- All seeds positions along time are visible simultaneously

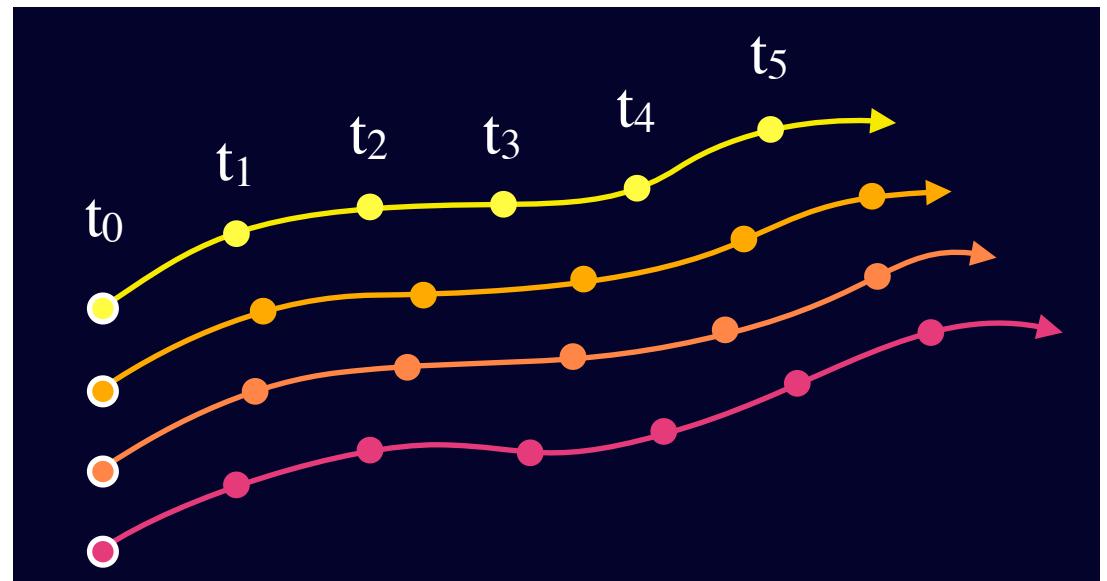
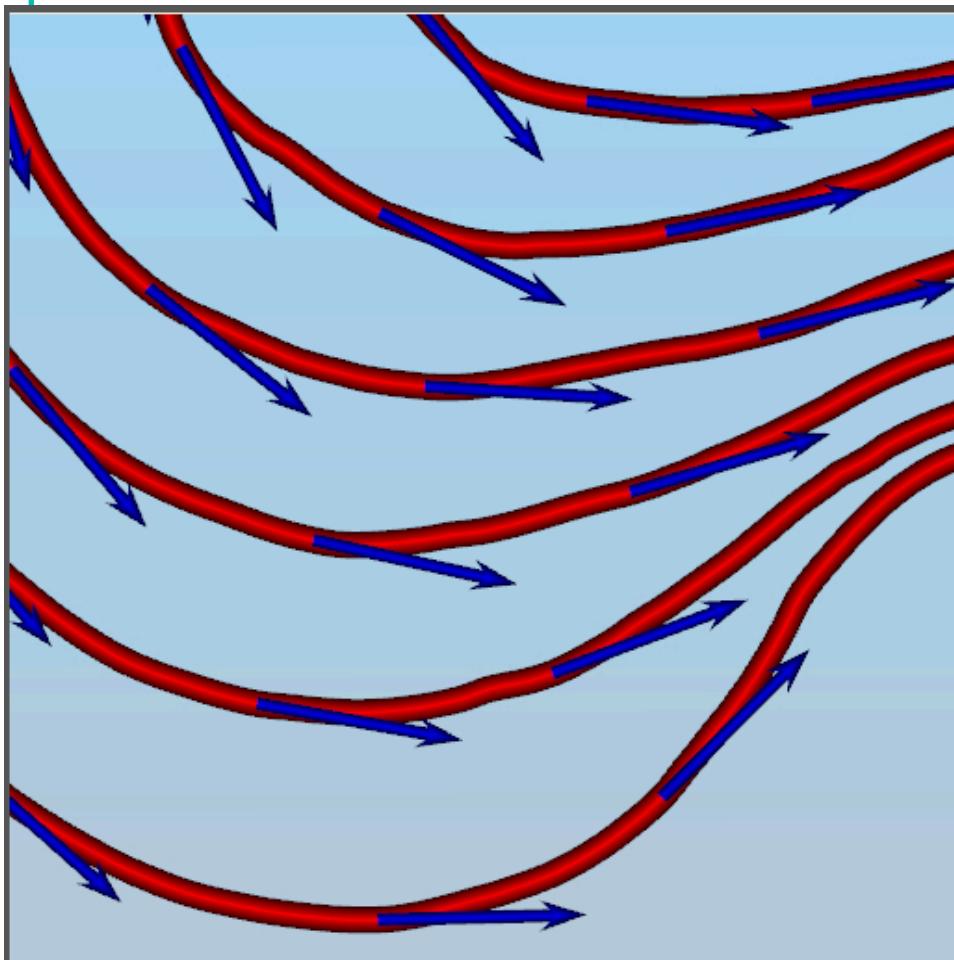
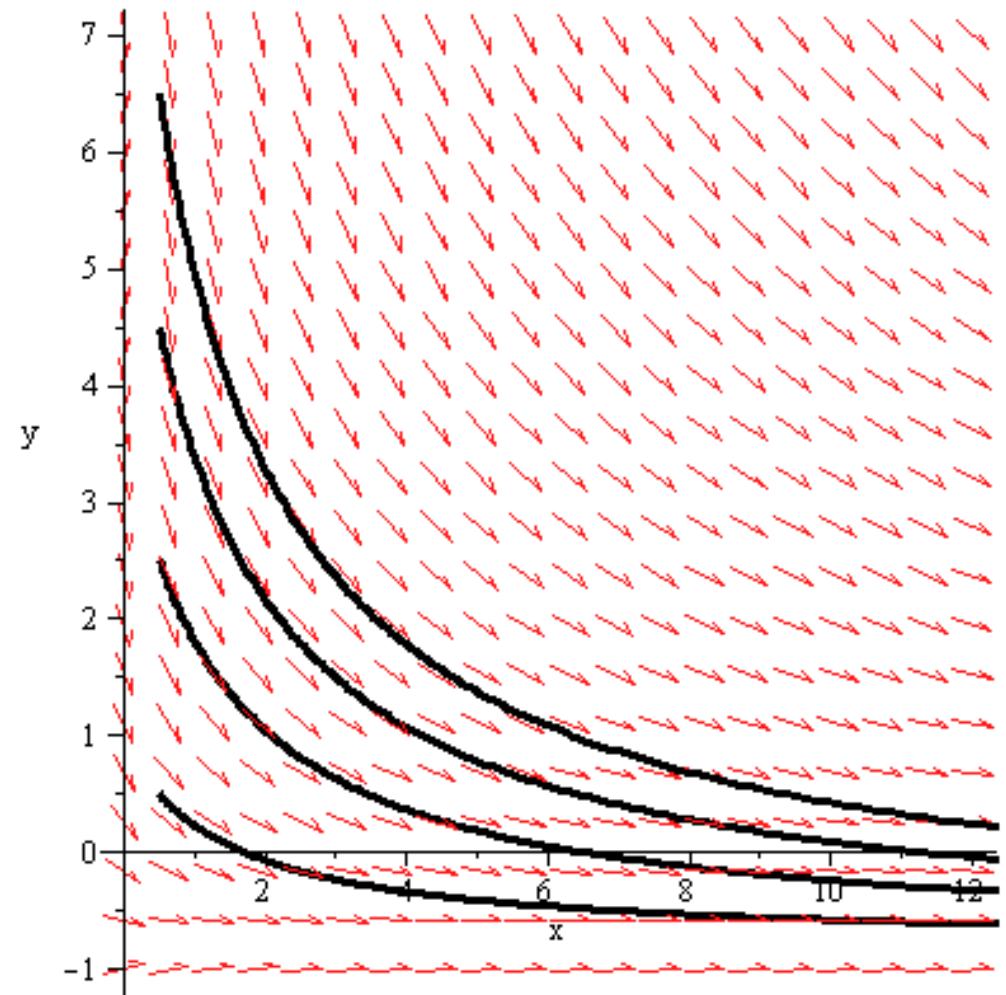


Image from Christoph Garth (UCDavis)

Flow visualization: streamlines

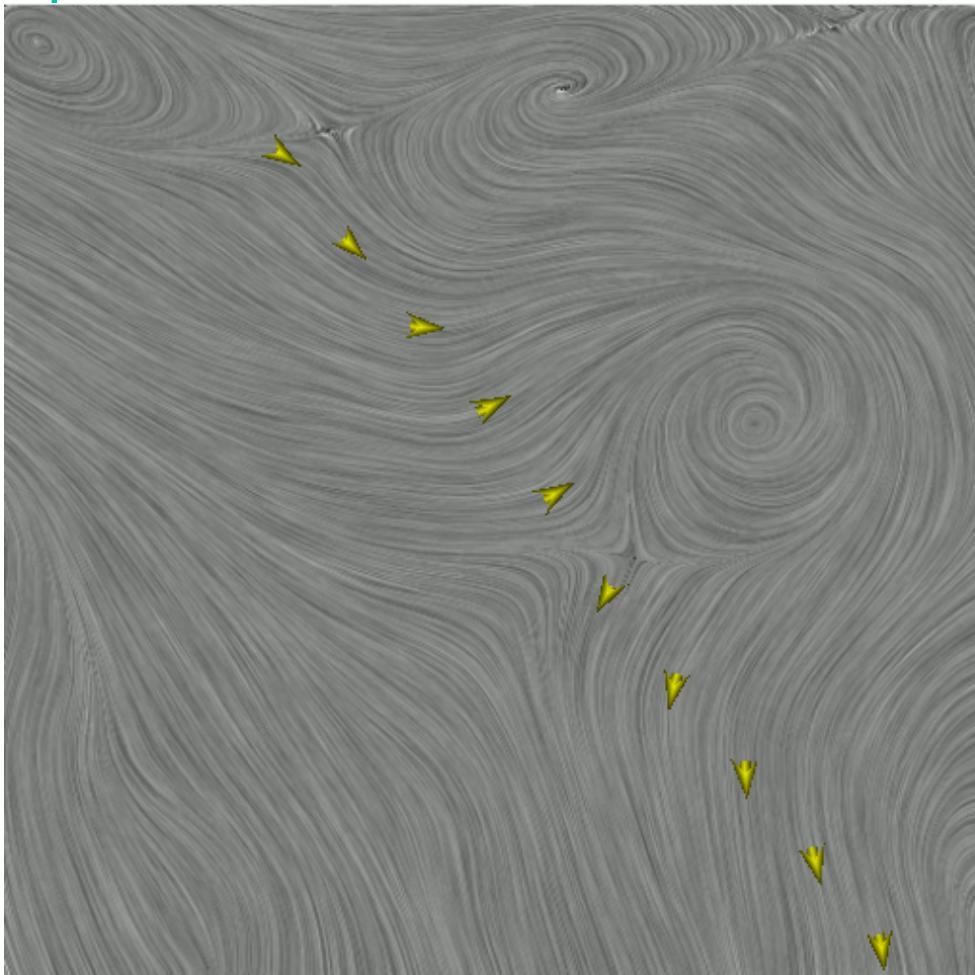


Source: <http://www3.nd.edu/~cwang11/2dflowvis.html>

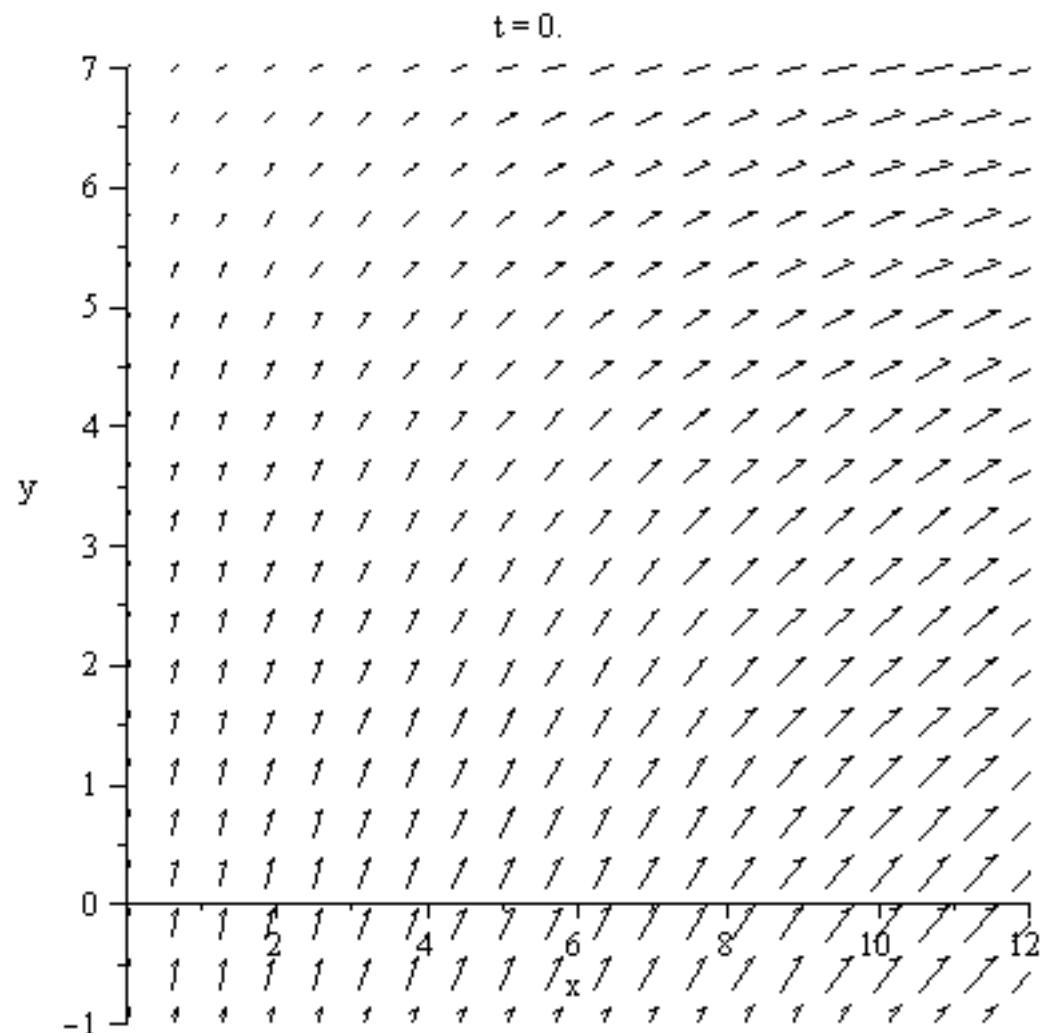


<http://ingforum.haninge.kth.se/armin/FLUID/dirfluid08.html>

Example of pathlines in an unsteady flow field



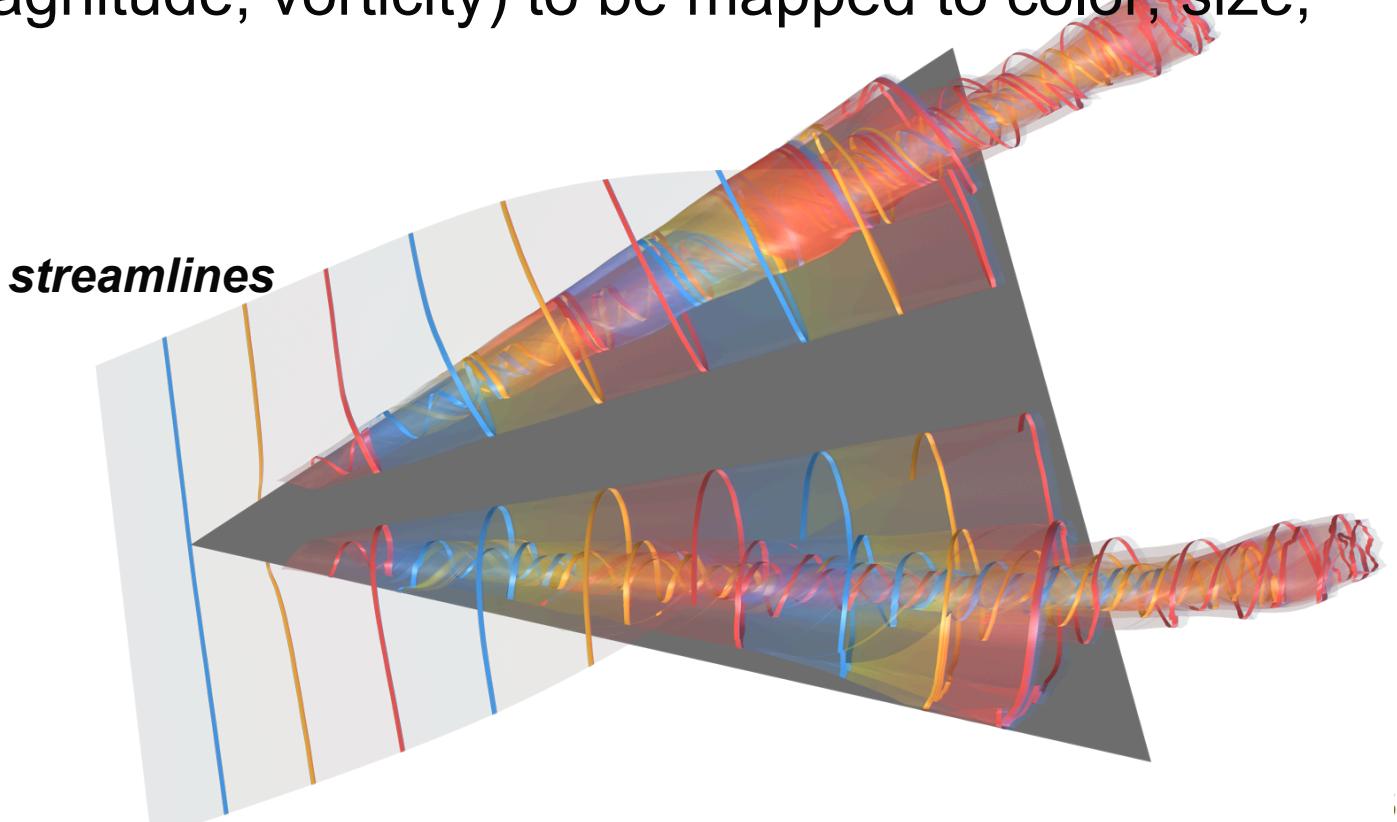
Source: <http://www3.nd.edu/~cwang11/2dflowvis.html>



<http://ingforum.haninge.kth.se/armin/FLUID/dirfluid08.html>

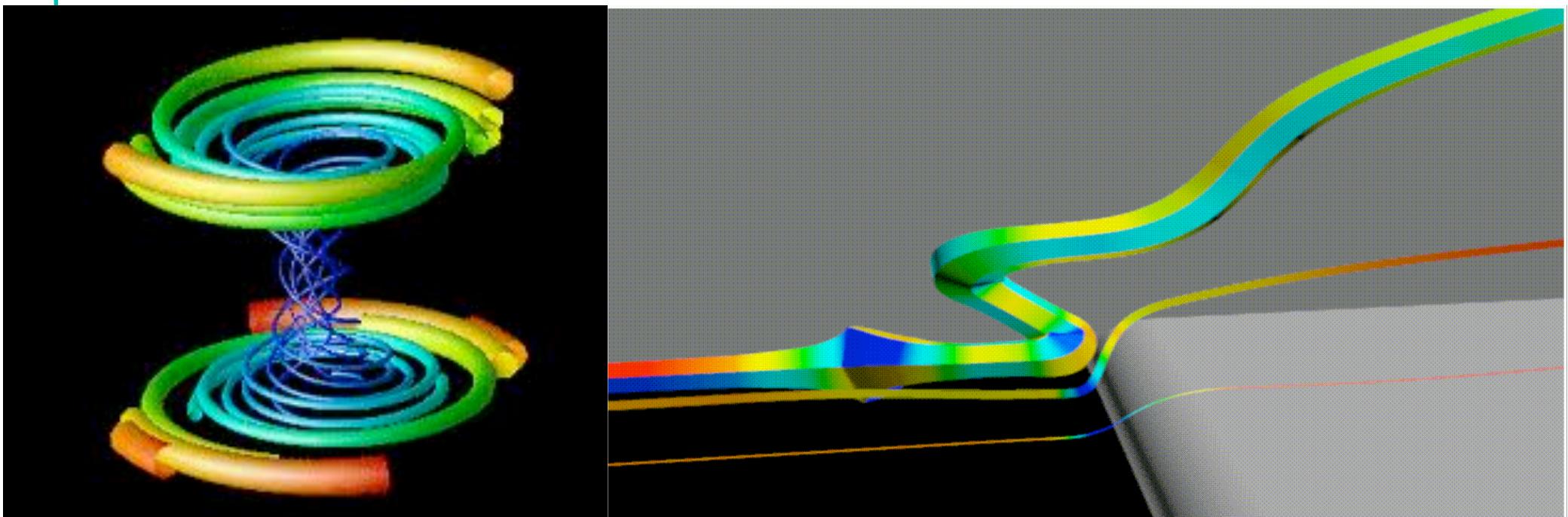
Flow visualization: stream-ribbons

- Stream-ribbons and stream-tubes
 - They are streamlines but with planar (ribbons) or solid (tubes) objects indicating the line. This allows other attributes of the field (magnitude, vorticity) to be mapped to color, size, or twist.



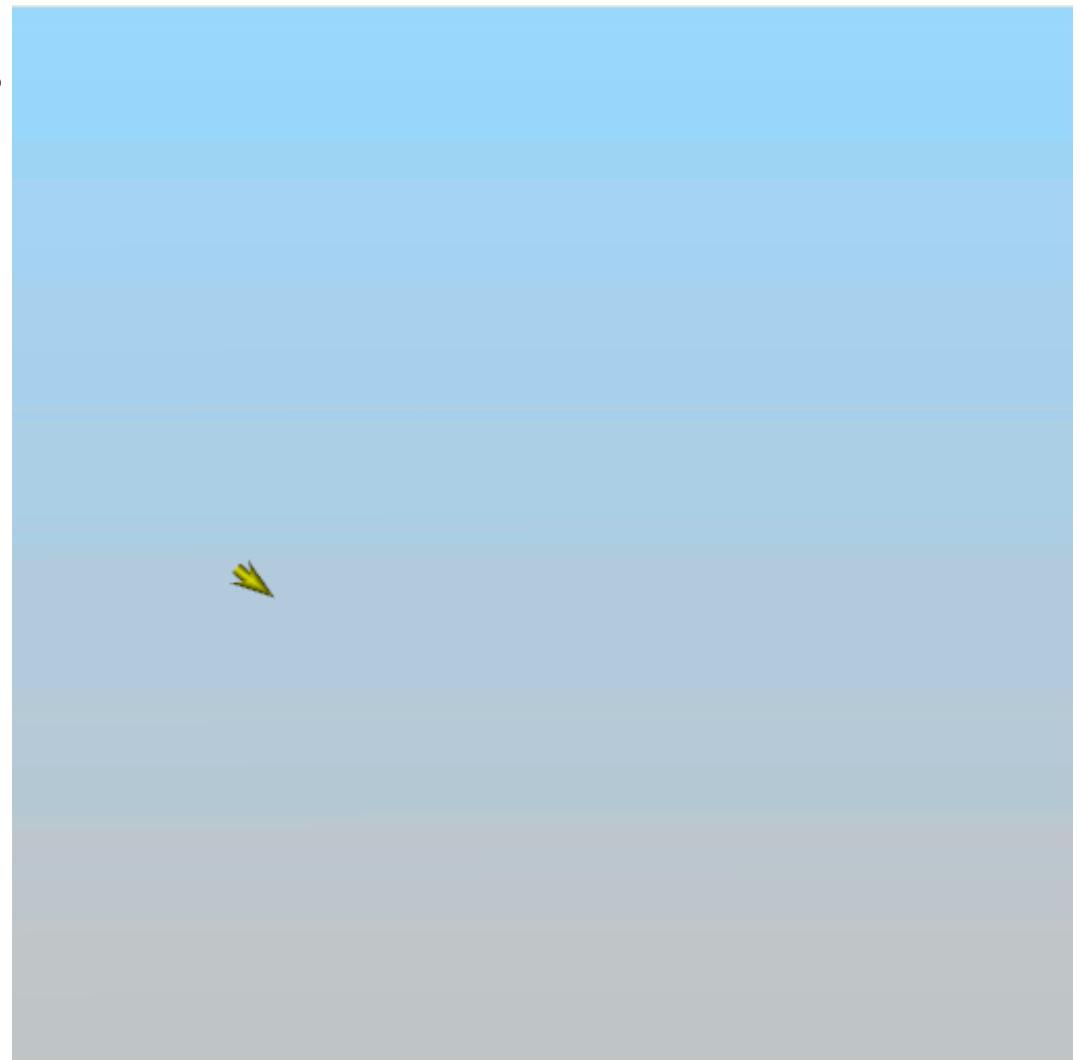
Flow visualization: stream-tubes

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Flow visualization: streaklines

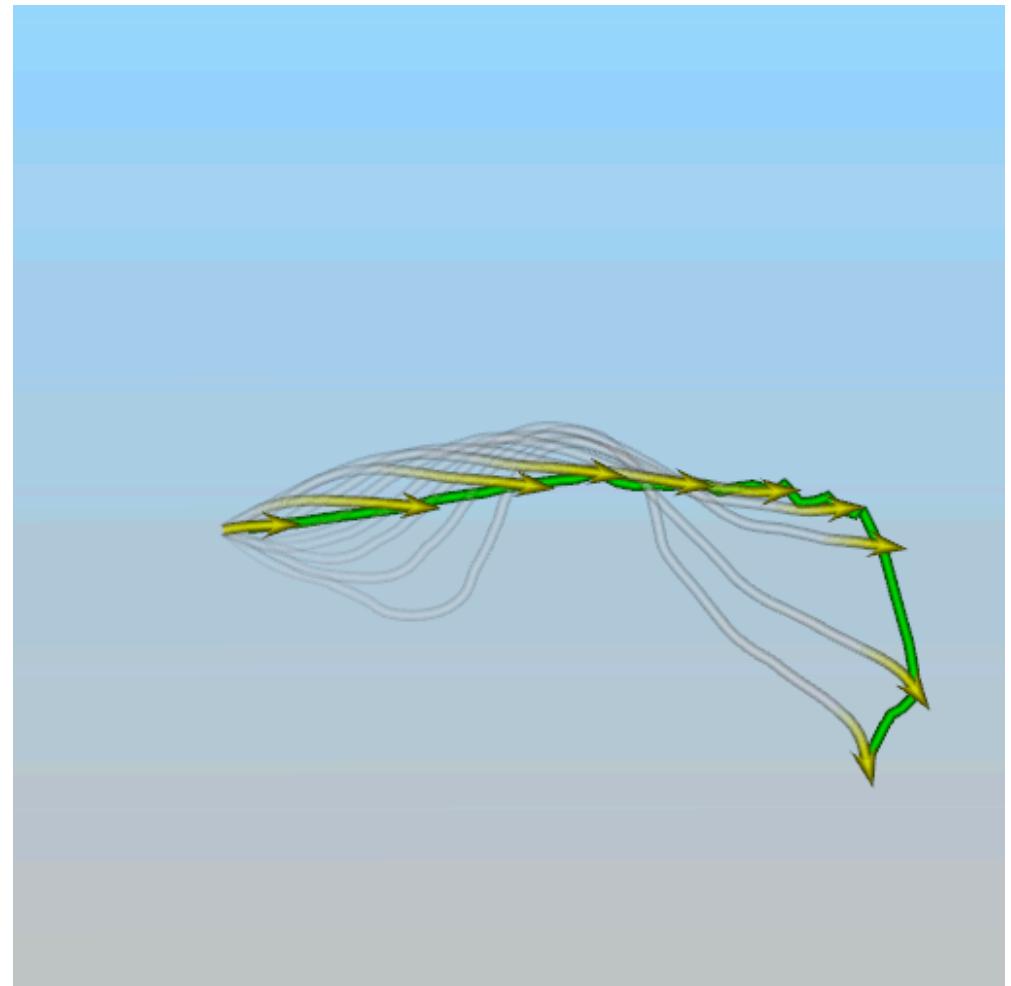
- A ***streakline*** is the locus of points of all the fluid particles that have passed continuously through a particular spatial point in the past.



Source: <http://www3.nd.edu/~cwang11/2dflowvis.html>

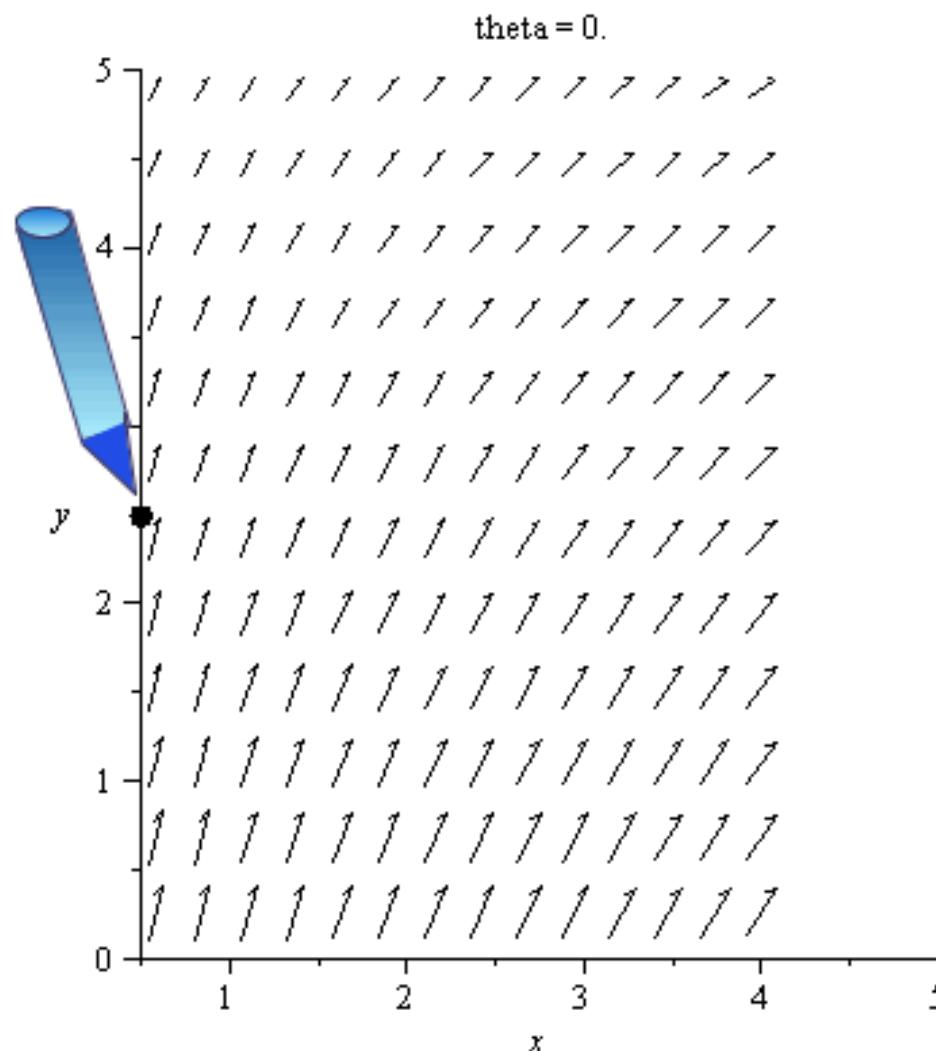
Flow visualization: streaklines

- A ***streakline*** is the locus of points of all the fluid particles that have passed continuously through a particular spatial point in the past.
- In the figure, the pathlines are drawn in yellow while the streakline is drawn in green.

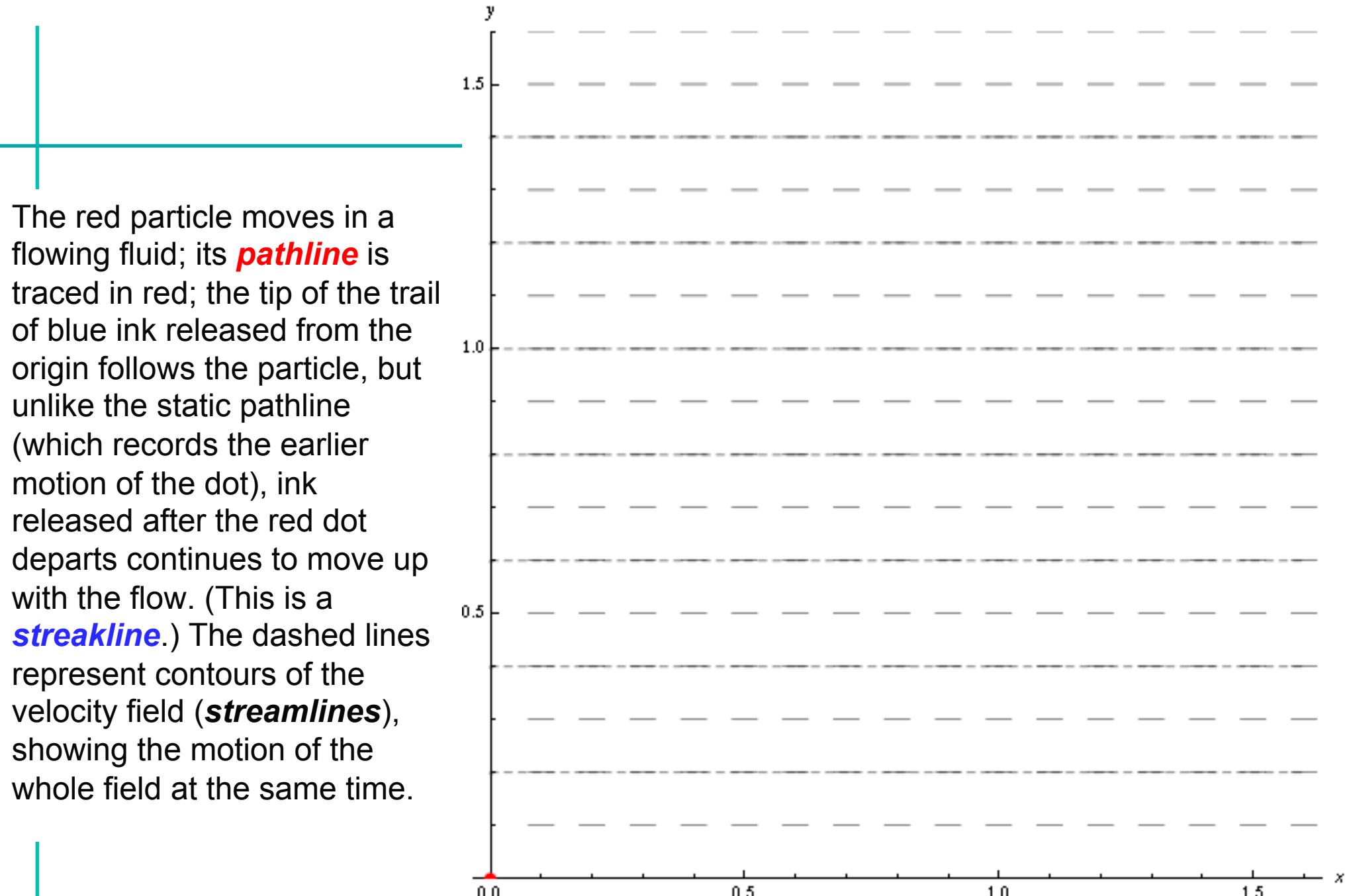


Source: <http://www3.nd.edu/~cwang11/2dflowvis.html>

Streaklines



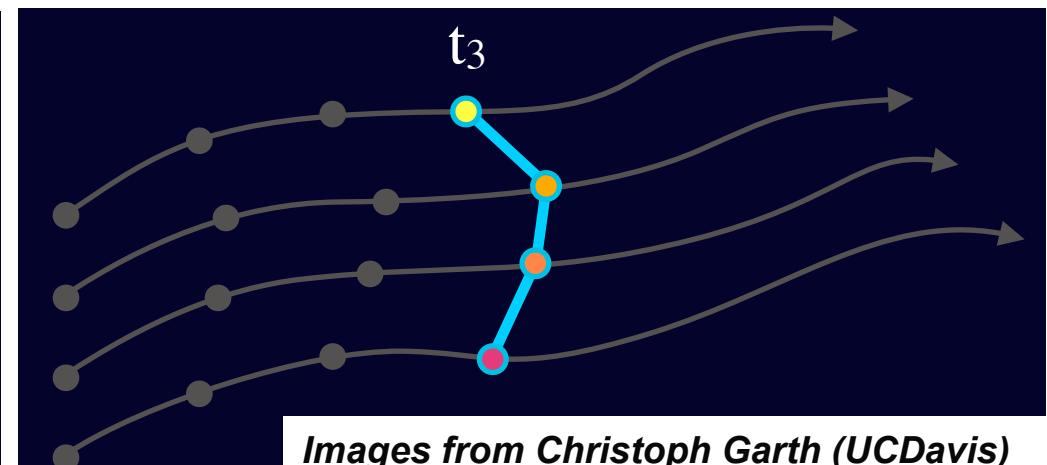
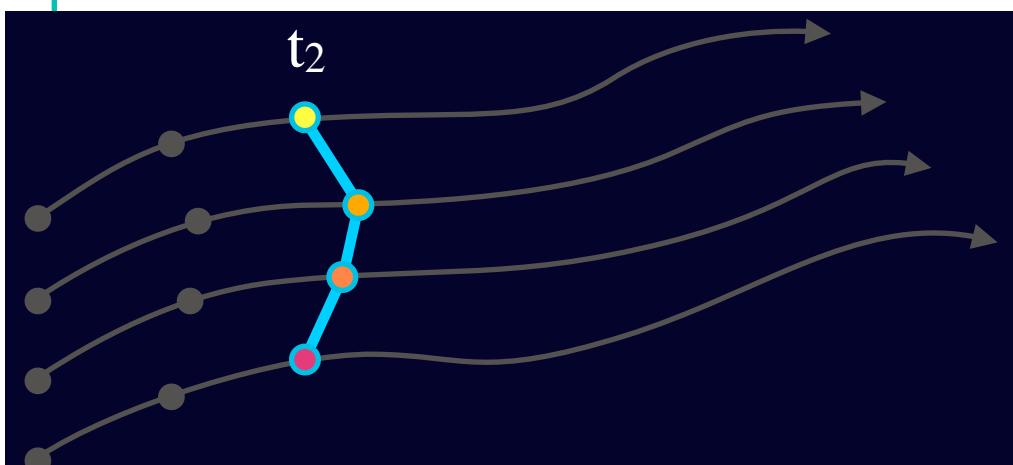
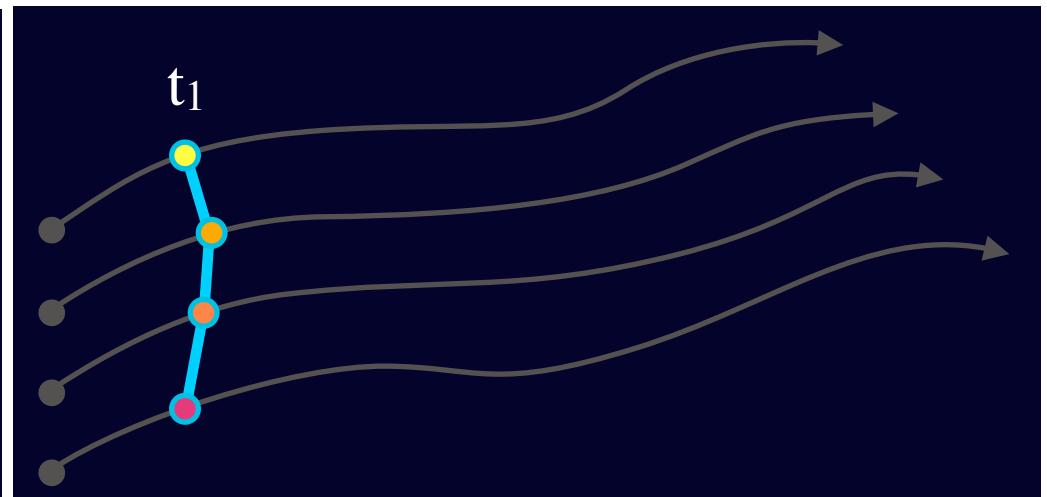
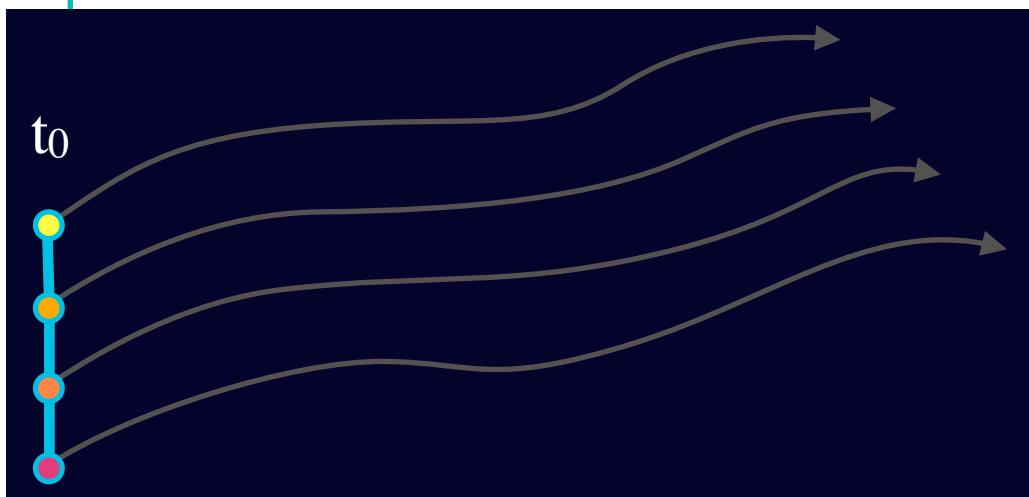
<http://ingforum.haninge.kth.se/armin/FLUID/dirfluid08.html>



http://en.wikipedia.org/wiki/File:Streaklines_and_pathlines_animation.gif

Flow visualization: timelines

- **Timelines** represent the line of particles emanating from a seed curve at each instant of time. No trajectories...

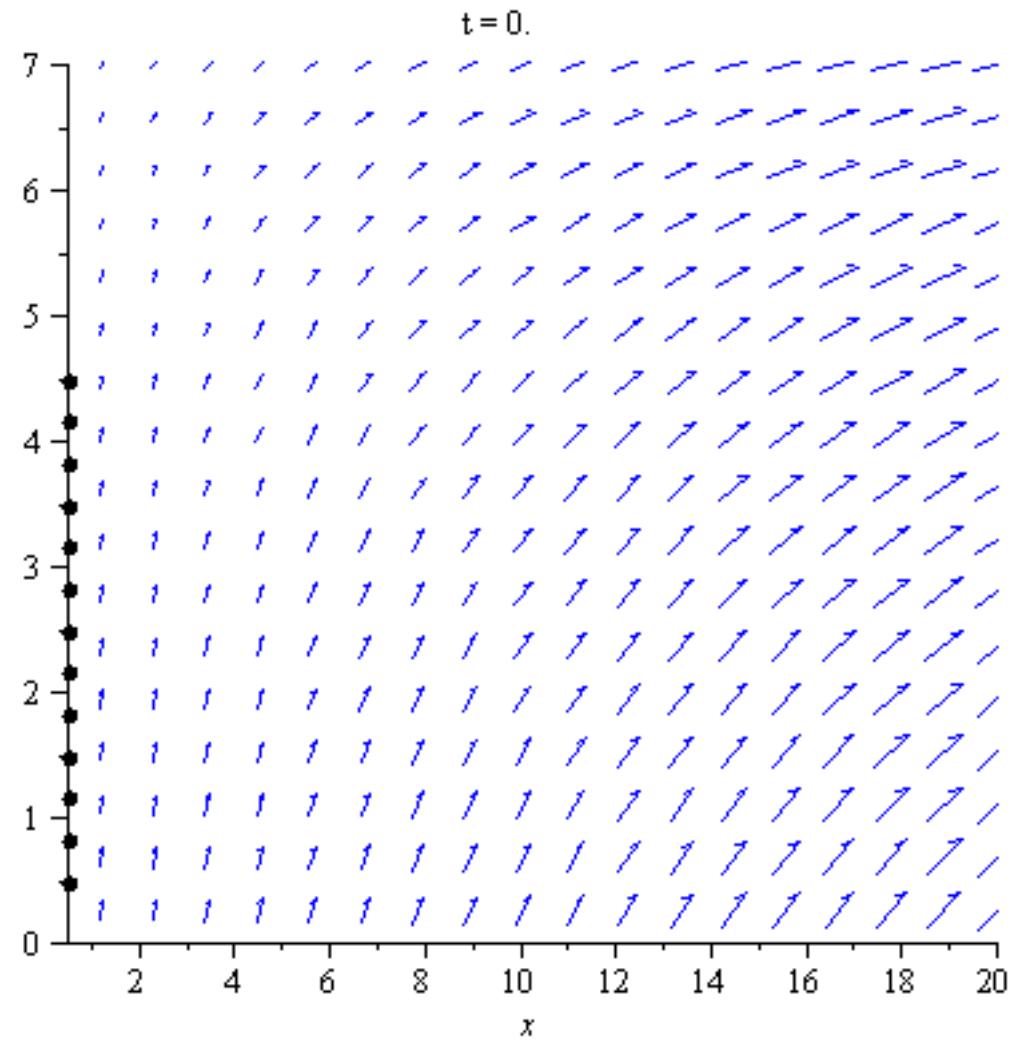


Images from Christoph Garth (UCDavis)

Timelines

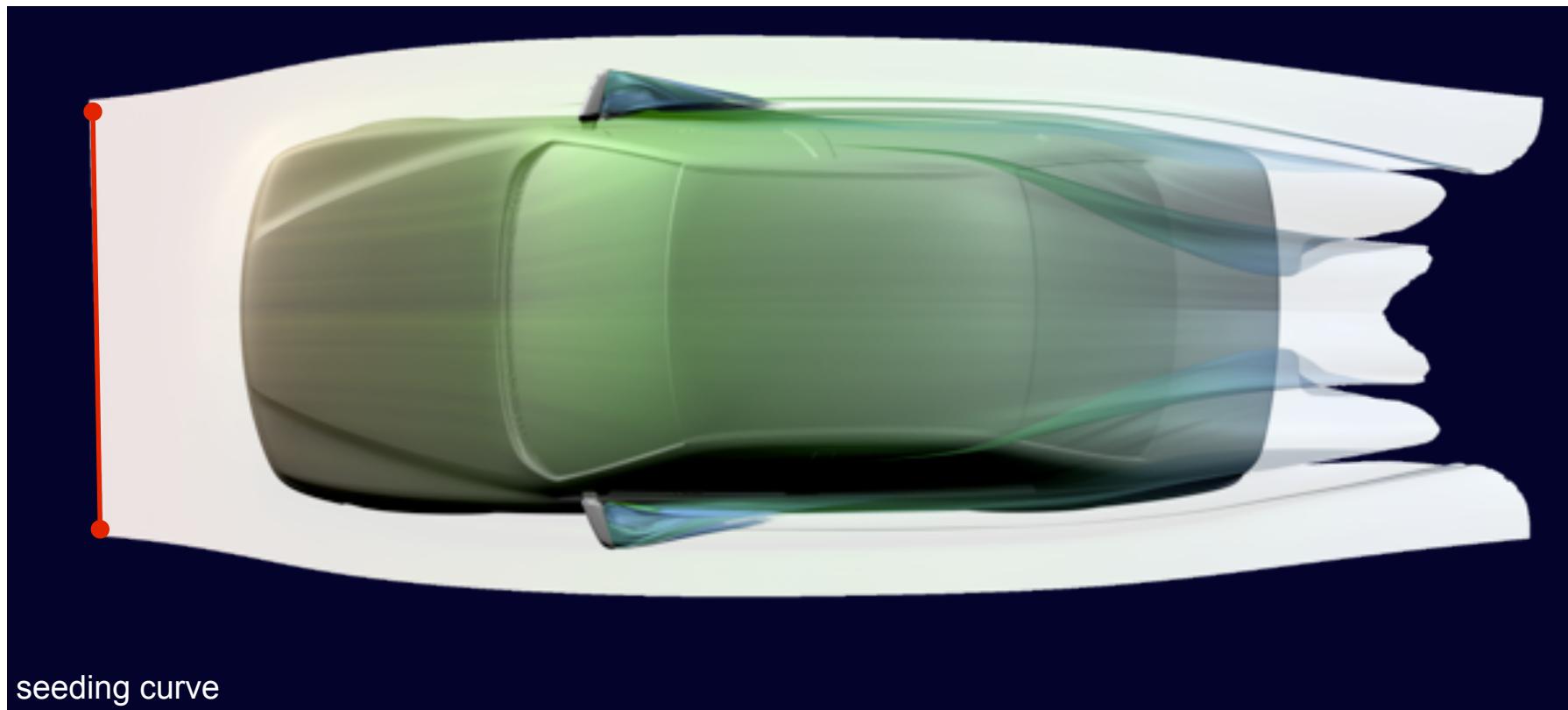


Source: <http://www3.nd.edu/~cwang11/2dflowvis.html>



<http://ingforum.haninge.kth.se/armin/FLUID/dirfluid08.html>

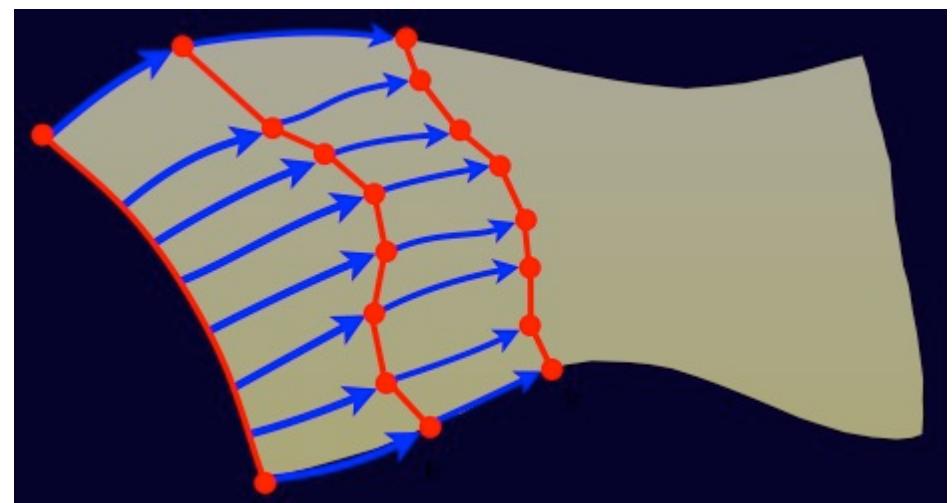
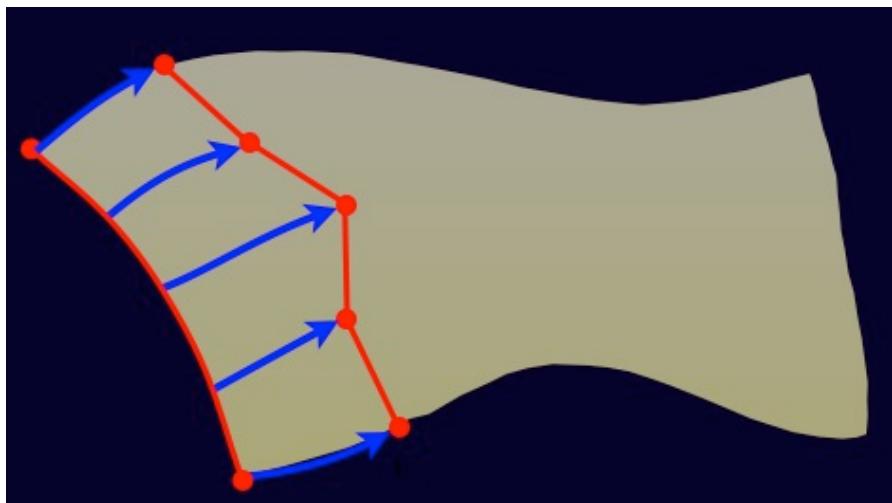
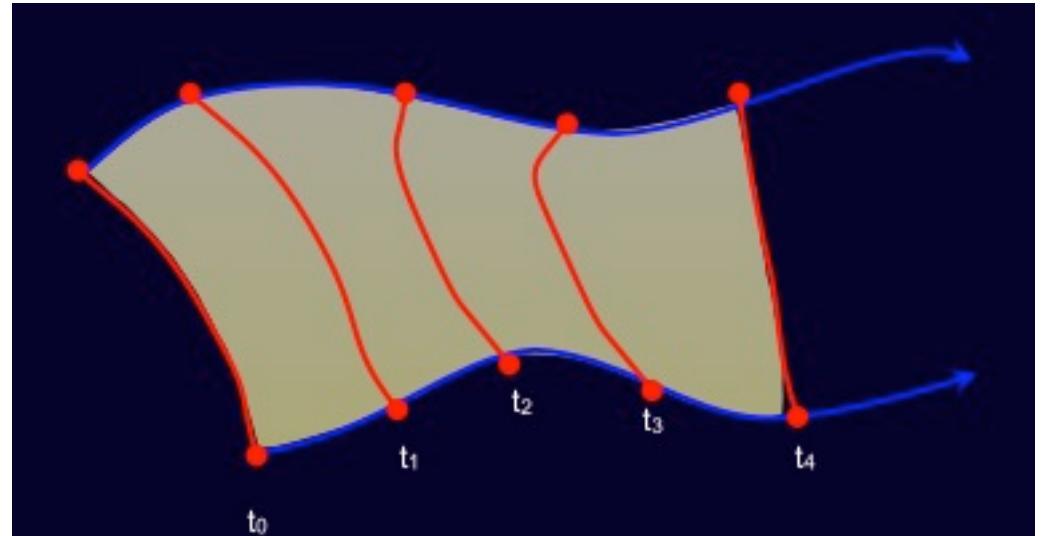
Flow visualization: integral surfaces



Images from Christoph Garth (UCDavis)

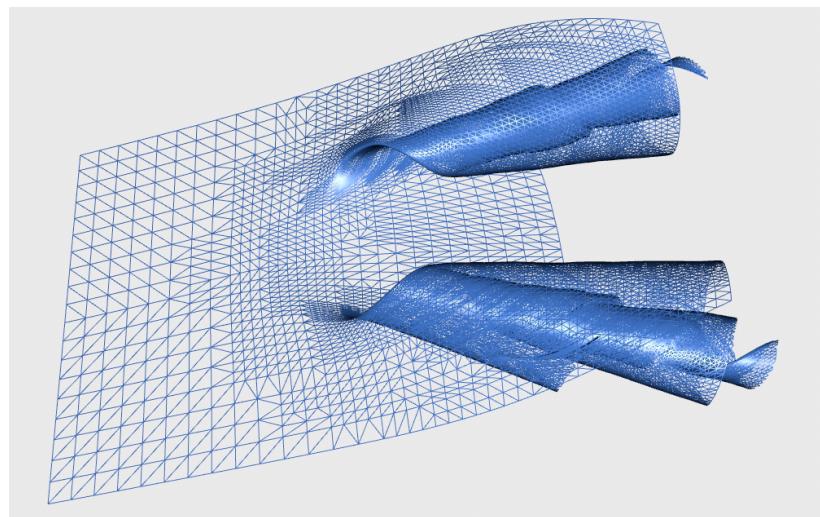
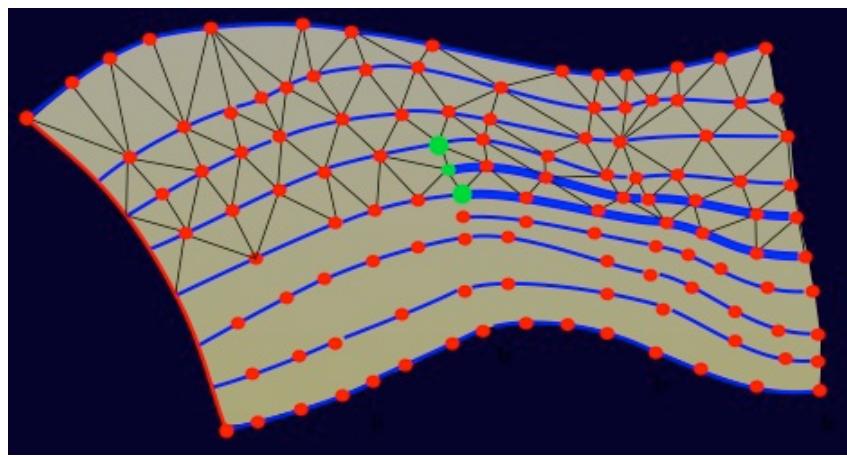
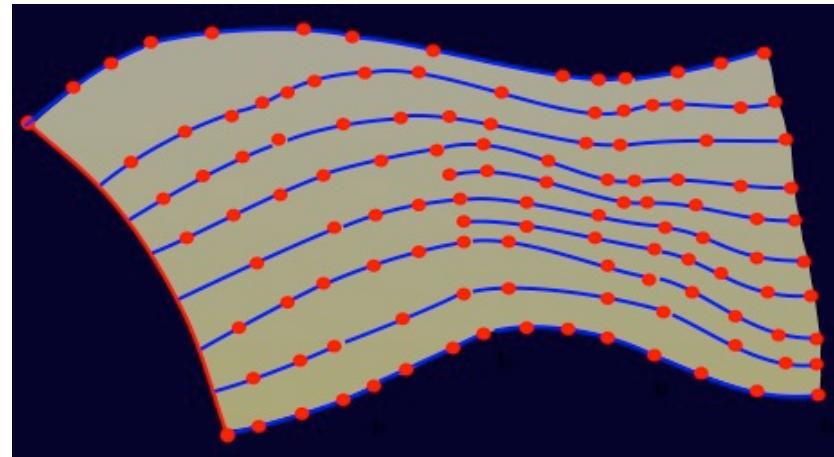
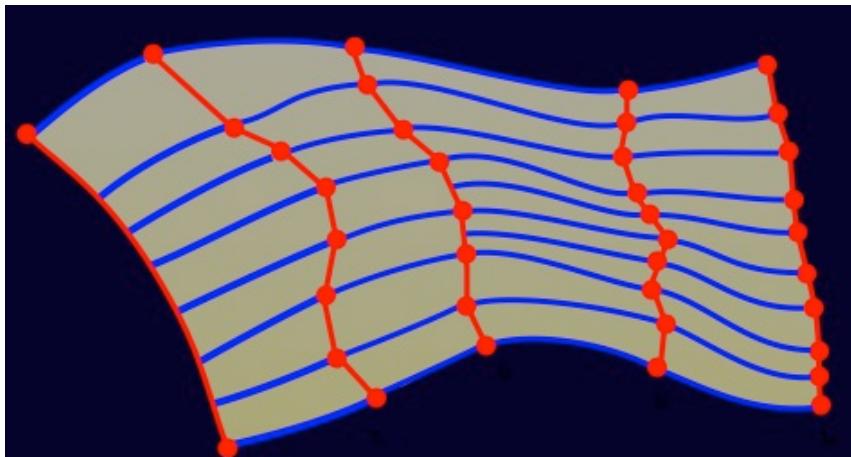
Flow visualization: integral surfaces

- Integral surfaces are also a set of time lines
- Points are inserted to improve resolution



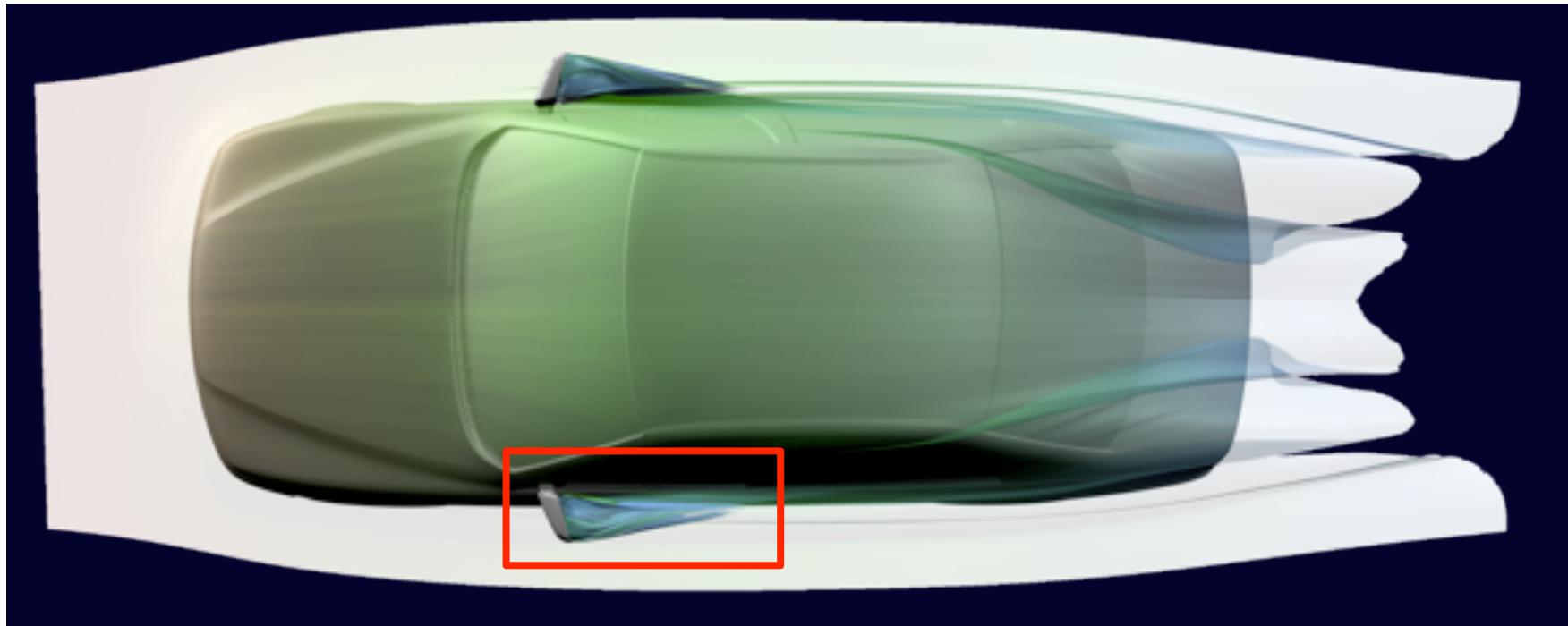
Images from Christoph Garth (UCDavis)

Flow visualization: integral surfaces



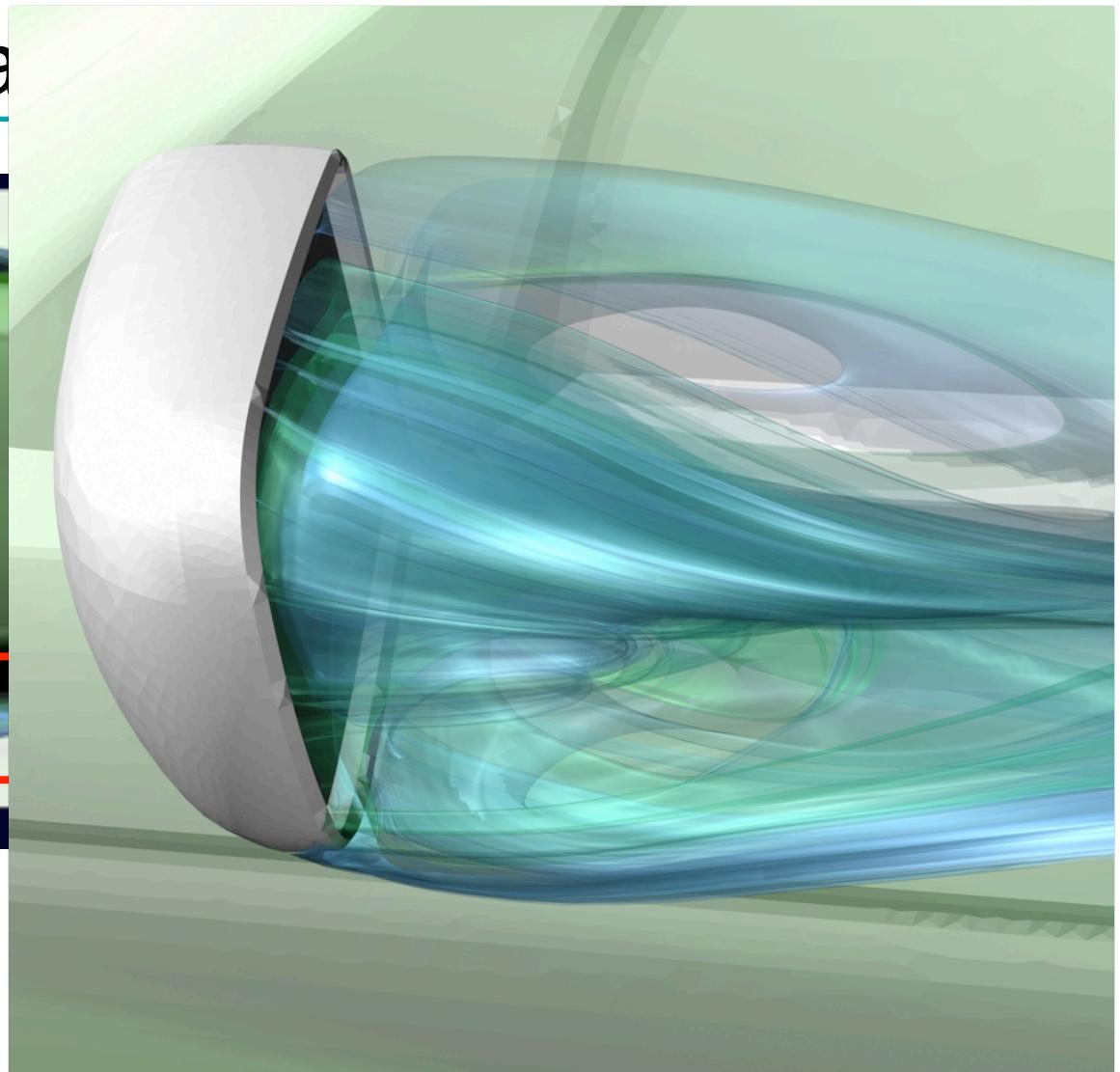
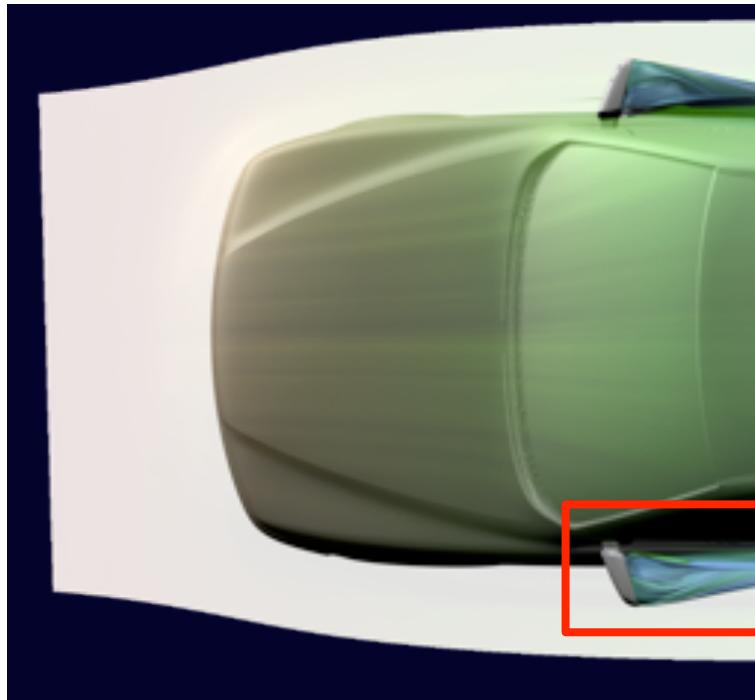
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Flow visualization



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