Additional techniques

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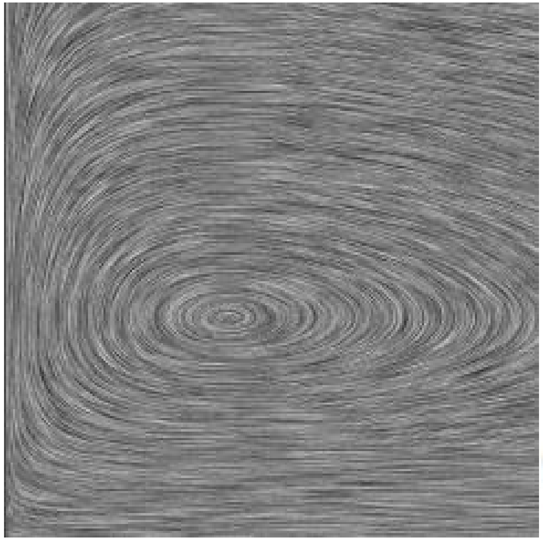
The story so far

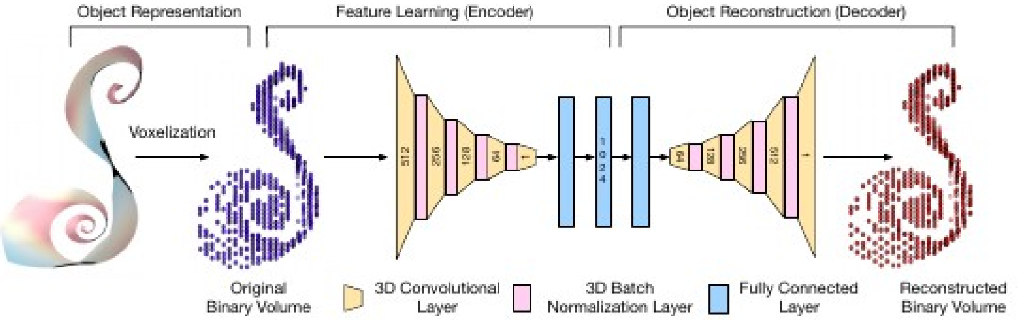
- Direct flow visualiation - glyphs
- Indirect flow visualization - streamlines, pathlines, streaklines

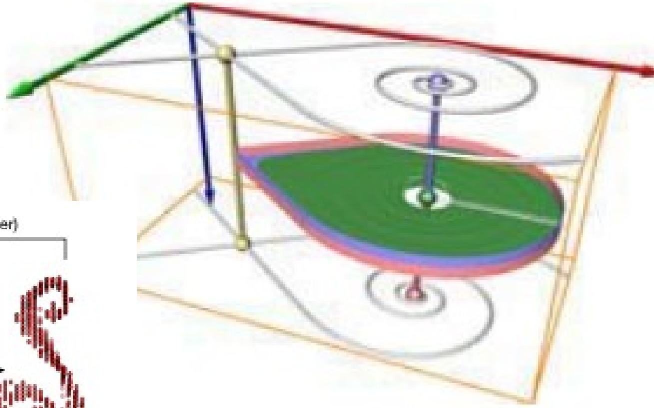
What else is there?

Other techniques

- Line integral convolution (LIC) - textures
- Feature-based flow visualization
- Topology-based flow visualization





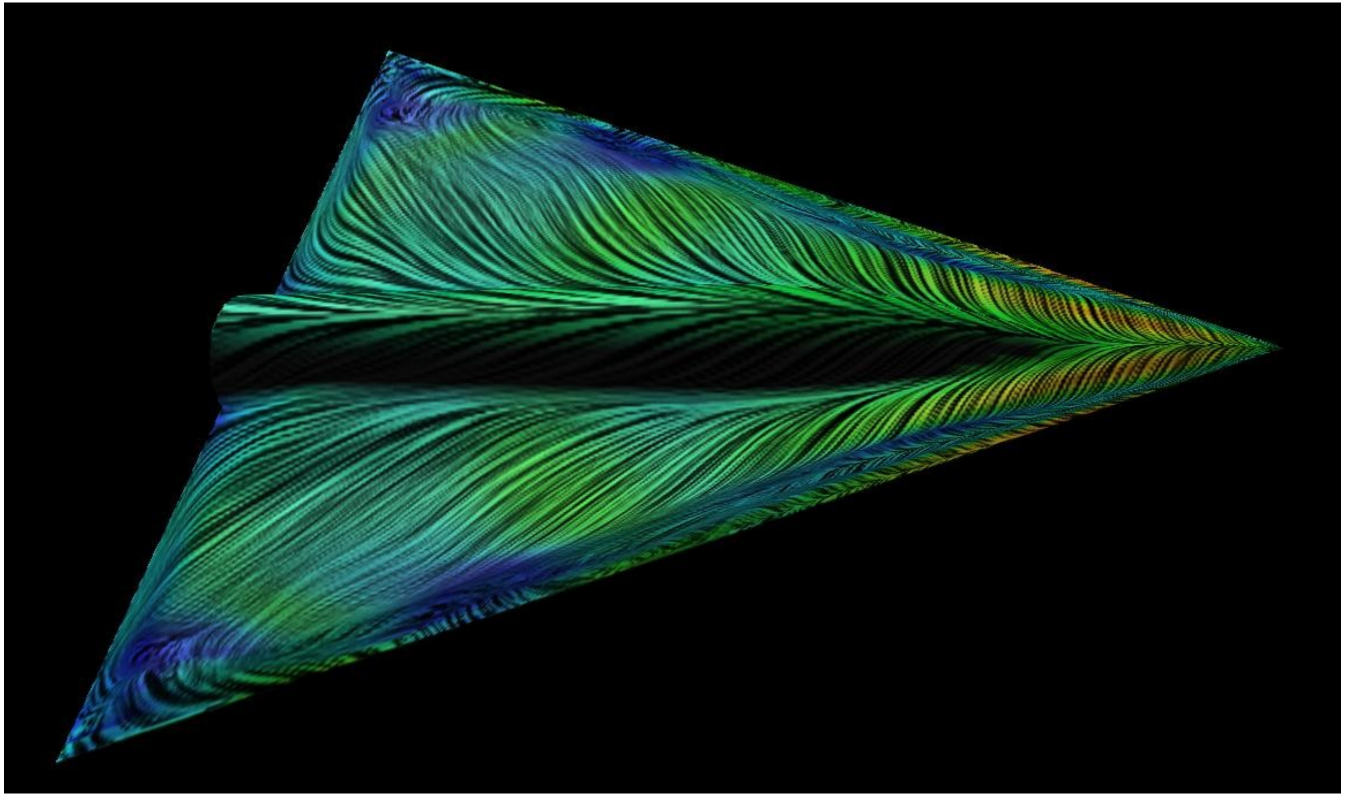


Line integral convolution

Line integral convolution

Useful for getting a general overview of the flow

- Convolution of white noise and a smoothing filter
- Streaks from streamlines through noise



How?

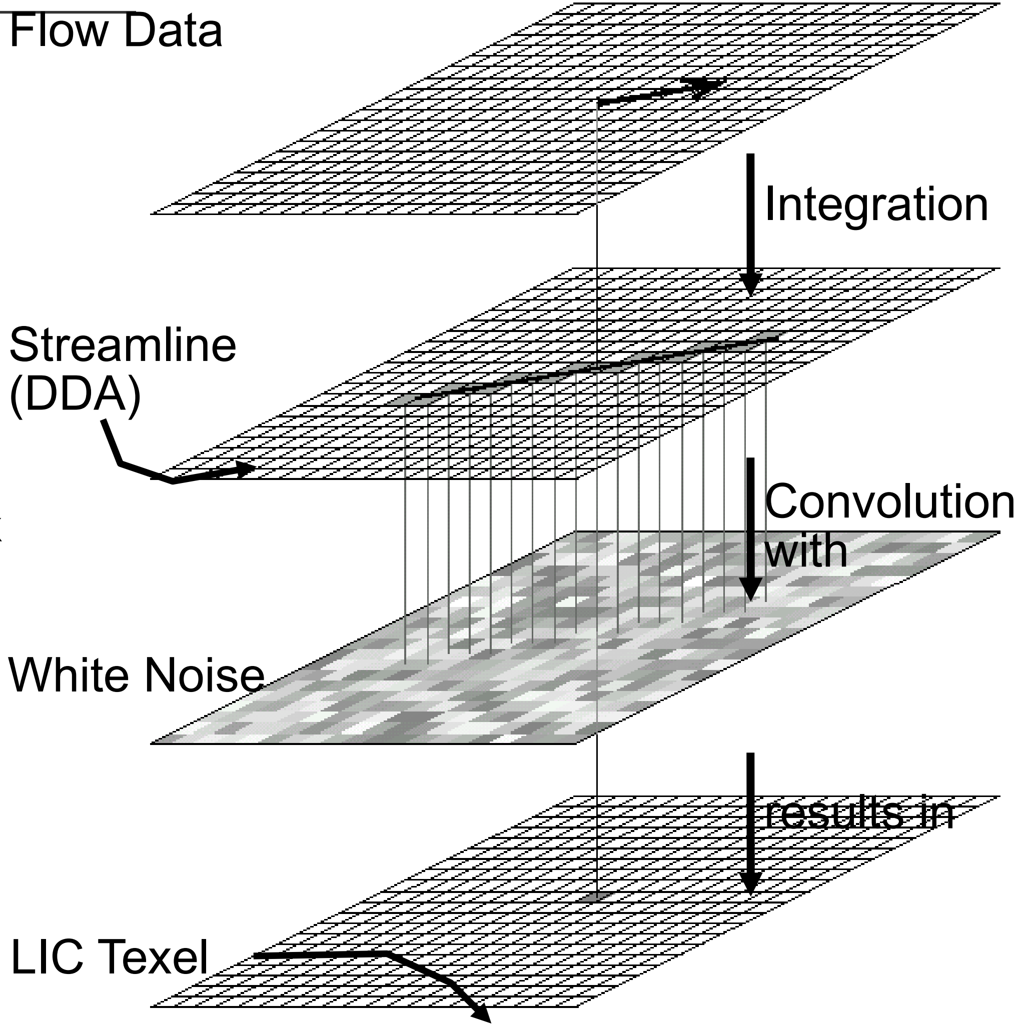
Inputs:

- flow data (v(x))
- white noise (n(x))
- filter (h(t)) --- Gaussian is popular choice

Algorithm for output image lic(x):

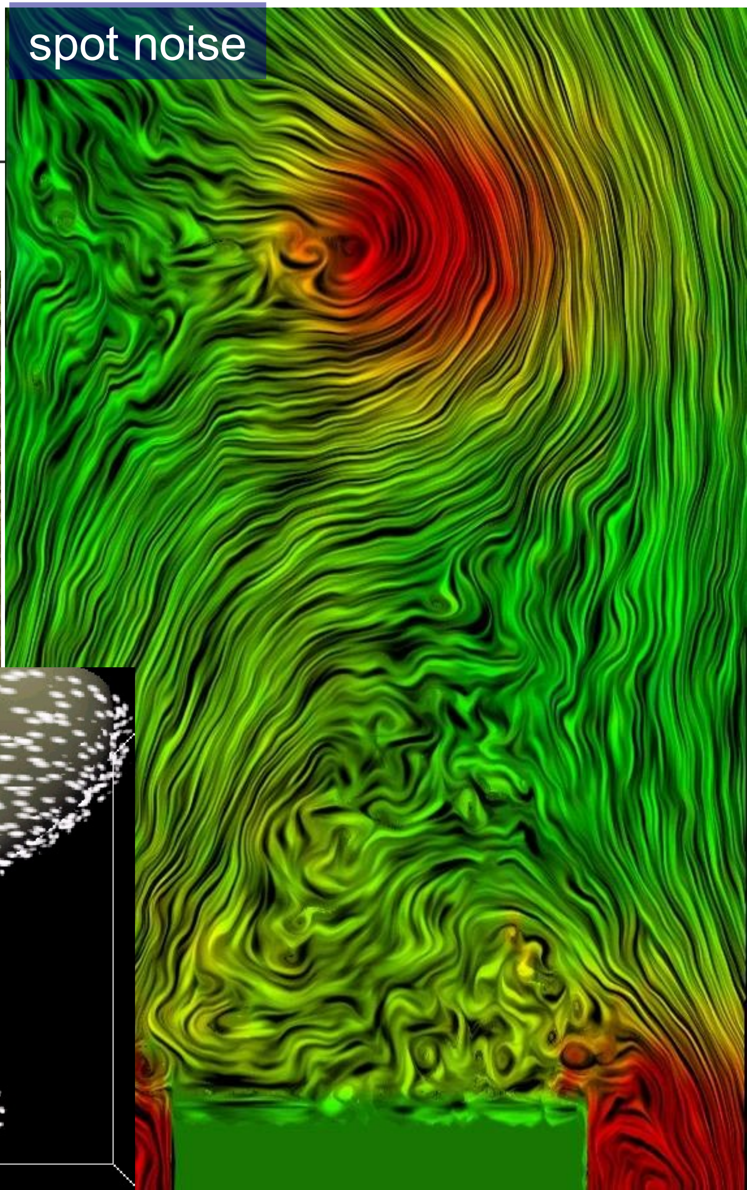
```
For each pixel location x:
  s_x(s) <- find streamline through x
  lic(x) <- 0
  For u = 0 to L // length of line
    lic(x) += n(s_x(u)) * h(u)
```

$$lic(x) = \int n(s_x(u))\, h(u)\, du$$

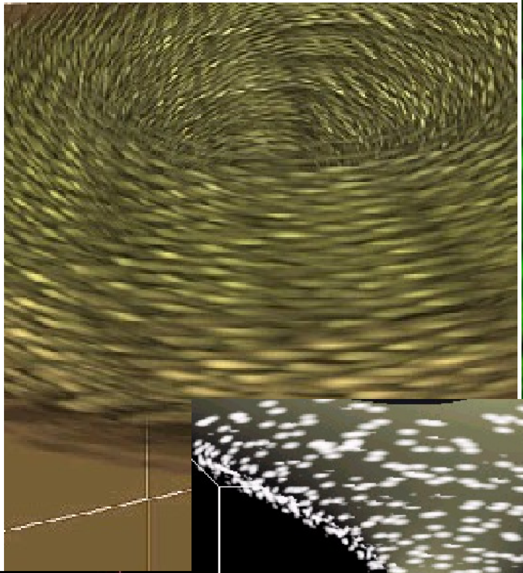


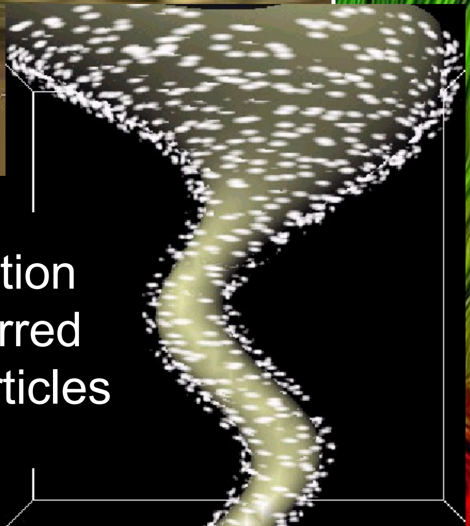
Alternatives to LIC

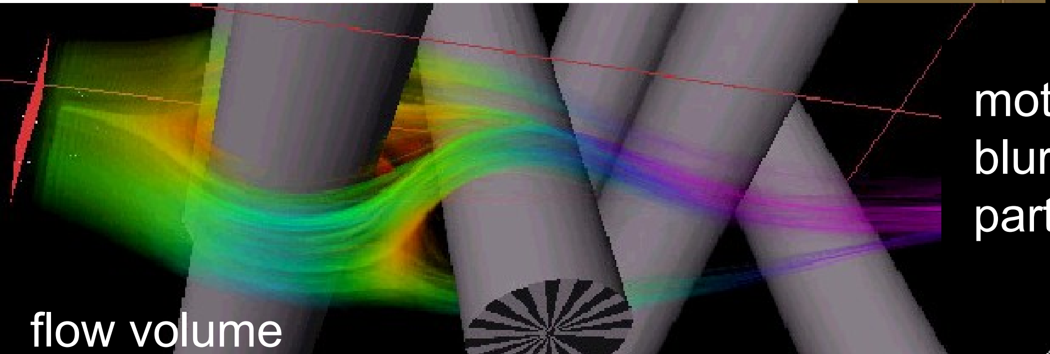
- Spot noise
- Textured splates
- Particle systems (weather maps)
- Flow volumes



textured splats







Feature-based flow visualization

Feature-based flow visualization

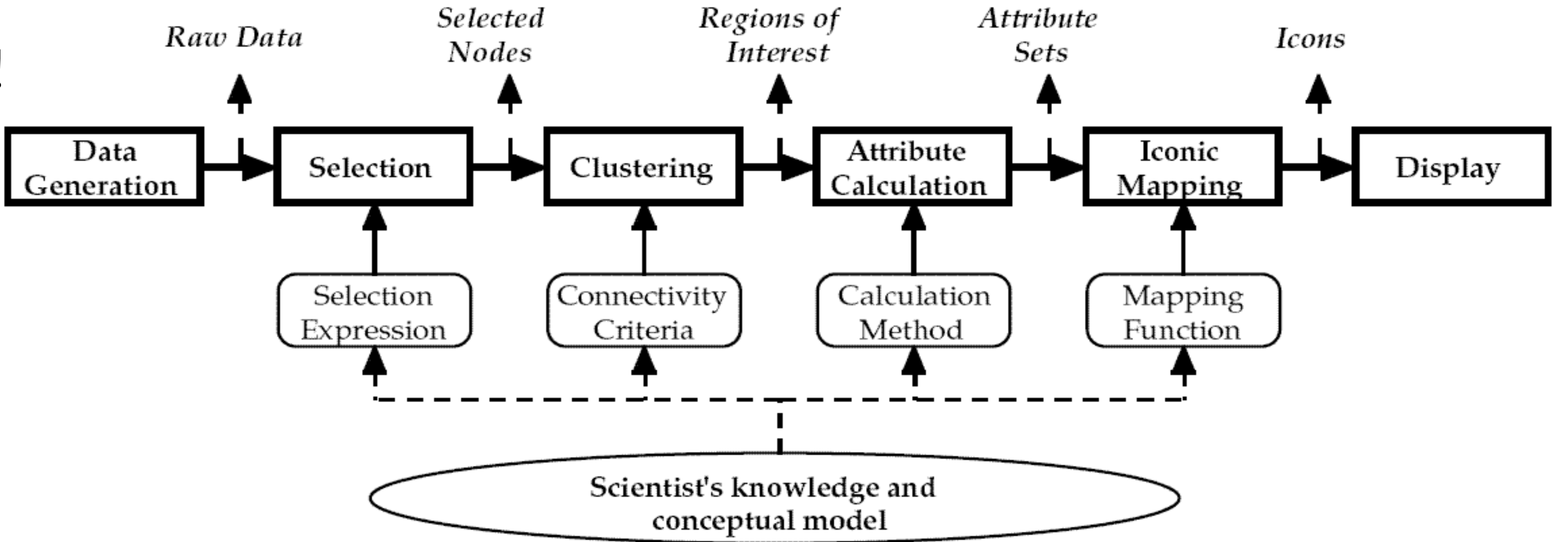
Feature : a prominent or distinctive aspect, quality, or characteristic of the flow field

1) Identify what are "interesting" features for the user

2) Design an algorithm to identify/extract these features

3) Show them to the user

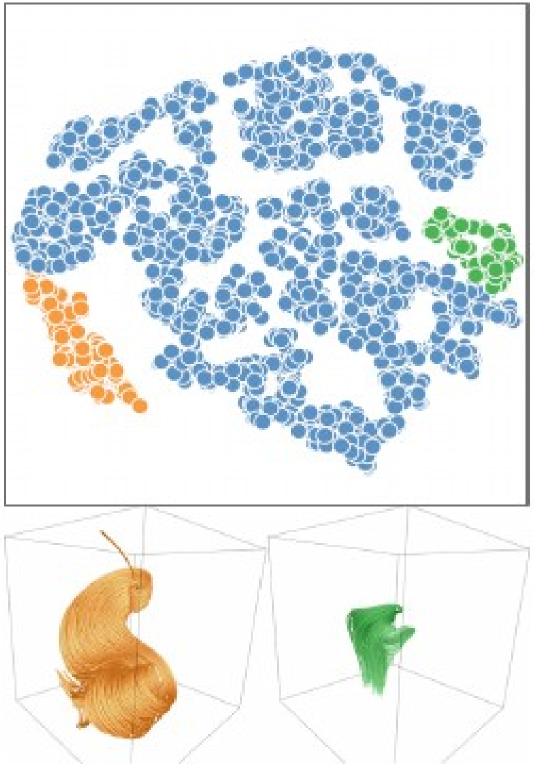
4) Profit!



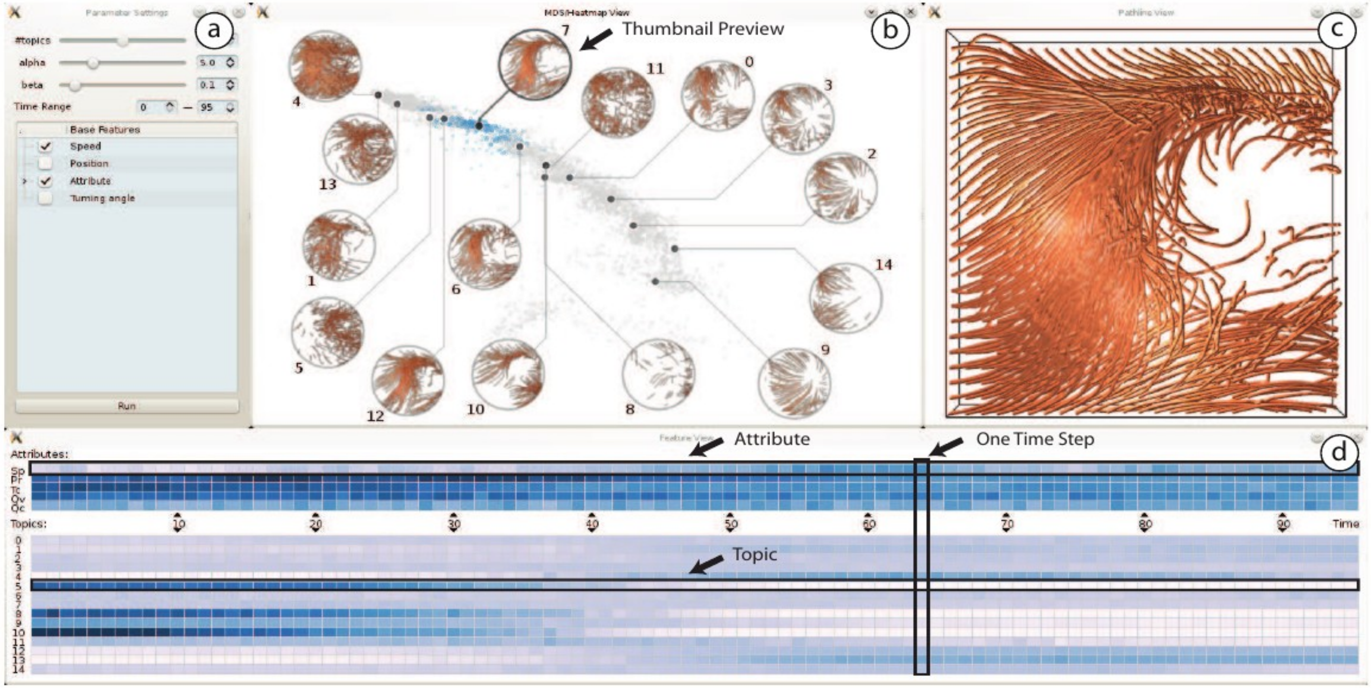
Motivation

- *data reduction* : original data set is represented with important features
- *perception* : visualization of 3D and 4D flow is problematic in the absence of feature-based techniques
- *new insight* : "new" characteristics of flow can be observed
- *technical advantages* : less memory consumption, faster interaction and rendering
- Good when you have clear idea of what to show

Examples



Han, Jun, Jun Tao, and Chaoli Wang. "FlowNet: A Deep Learning Framework for Clustering and Selection of Streamlines and Stream Surfaces." IEEE Transactions on Visualization and Computer Graphics, 2018, 1–1. https://doi.org/10.1109/TVCG.2018.2880207.



Hong, Fan, Chufan Lai, Hanqi Guo, Enya Shen, Xiaoru Yuan, and Sikun Li. "FLDA: Latent Dirichlet Allocation Based Unsteady Flow Analysis." IEEE Transactions on Visualization and Computer Graphics 20, no. 12 (December 2014): 2545–54. https://doi.org/10.1109/TVCG.2014.2346416.

Topology-based flow visualization

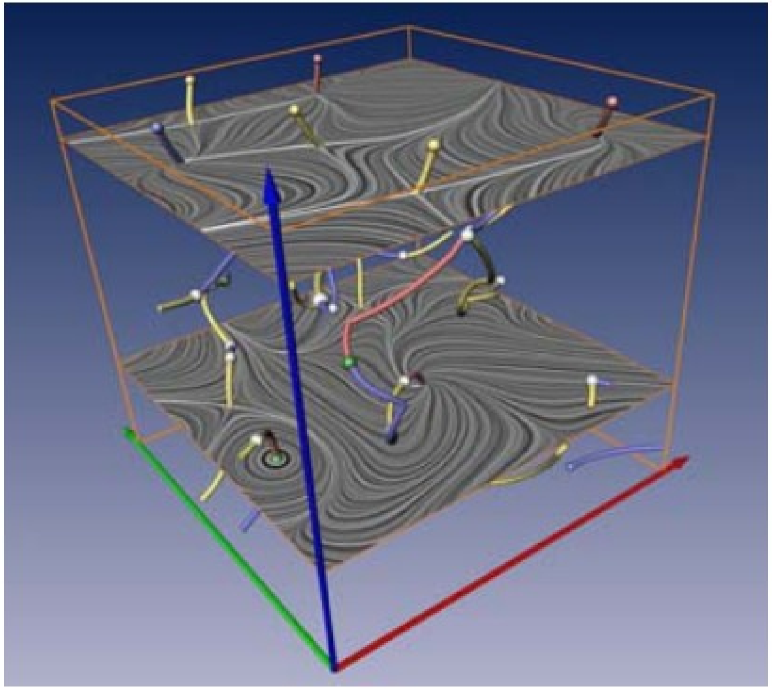
Introduction

Topological data analysis : Focuses on extracting critical points and how they relate to each other

Critical points : (Usually) locations of a function where gradient is 0

Singularities : Areas where the flow velocity is zero – e.g. sources, sinks

- Connectivity (*topology*) between the singularies is analyzed
- Topology of a vector field can be called "skeleton" of the flow
- Good for feature tracking

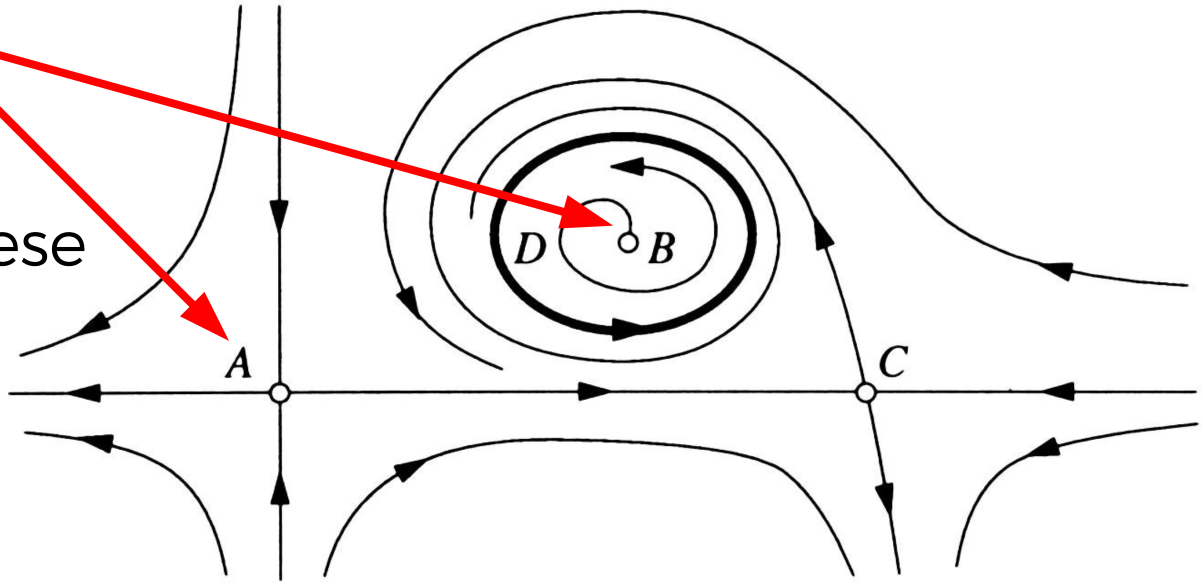


Theisel, H., T. Weinkauf, H.-C. Hege, and H.-P. Seidel. “Stream Line and Path Line Oriented Topology for 2D Time-Dependent Vector Fields.” In IEEE Visualization 2004, 321–28, 2004. https://doi.org/10.1109/VISUAL.2004.99.

Flow topology

- Critical points ($v(x) = 0$)
- Cycles ($s\_x(t+T) = s\_x(t)$)
- Connections between these

Separatrices : streamlines connecting critcal points



Flow topology

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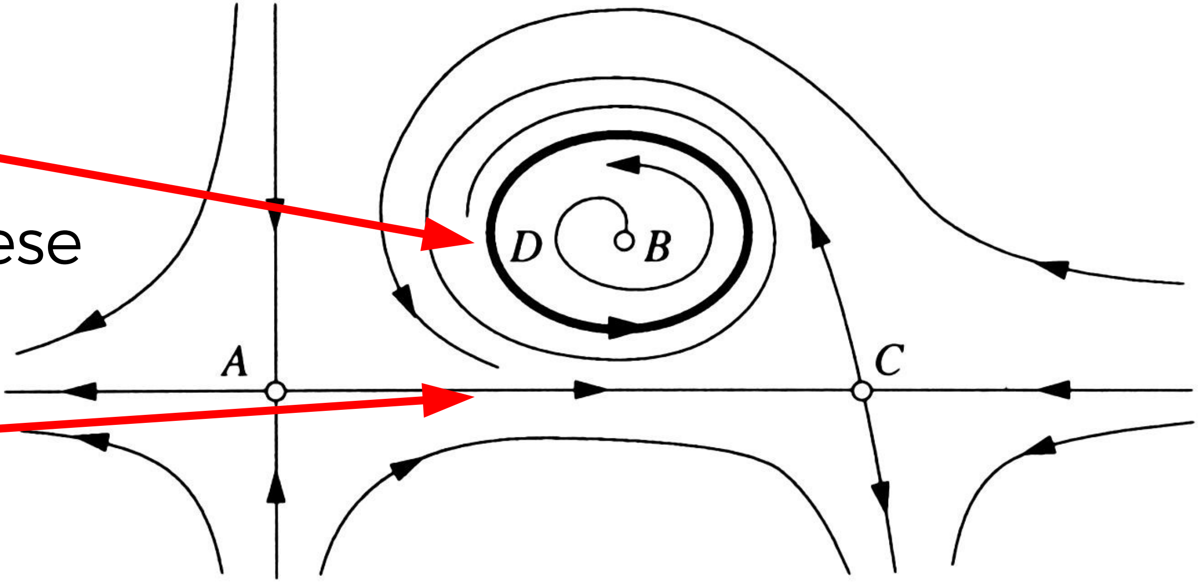

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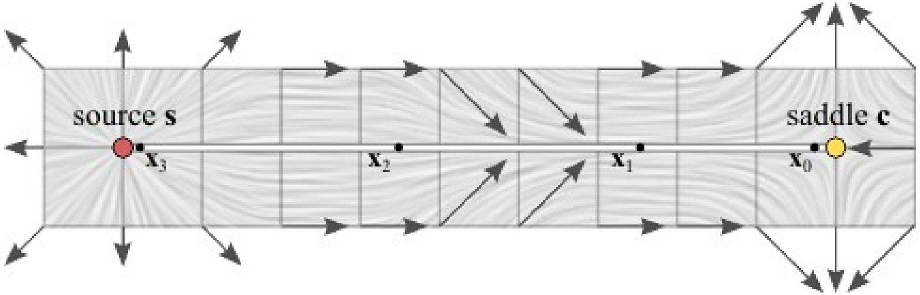
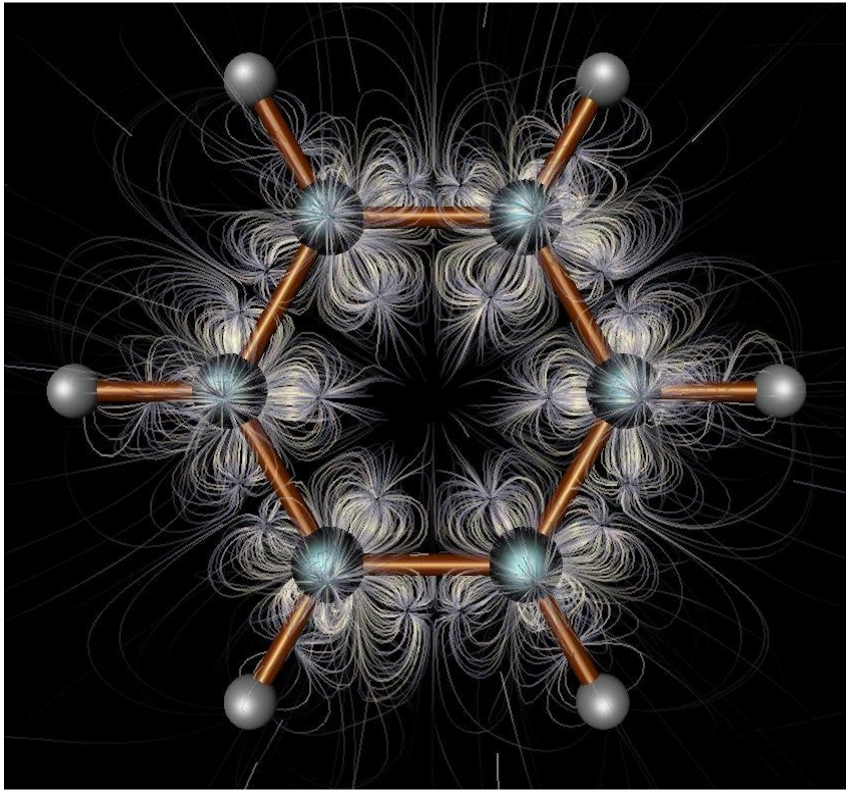
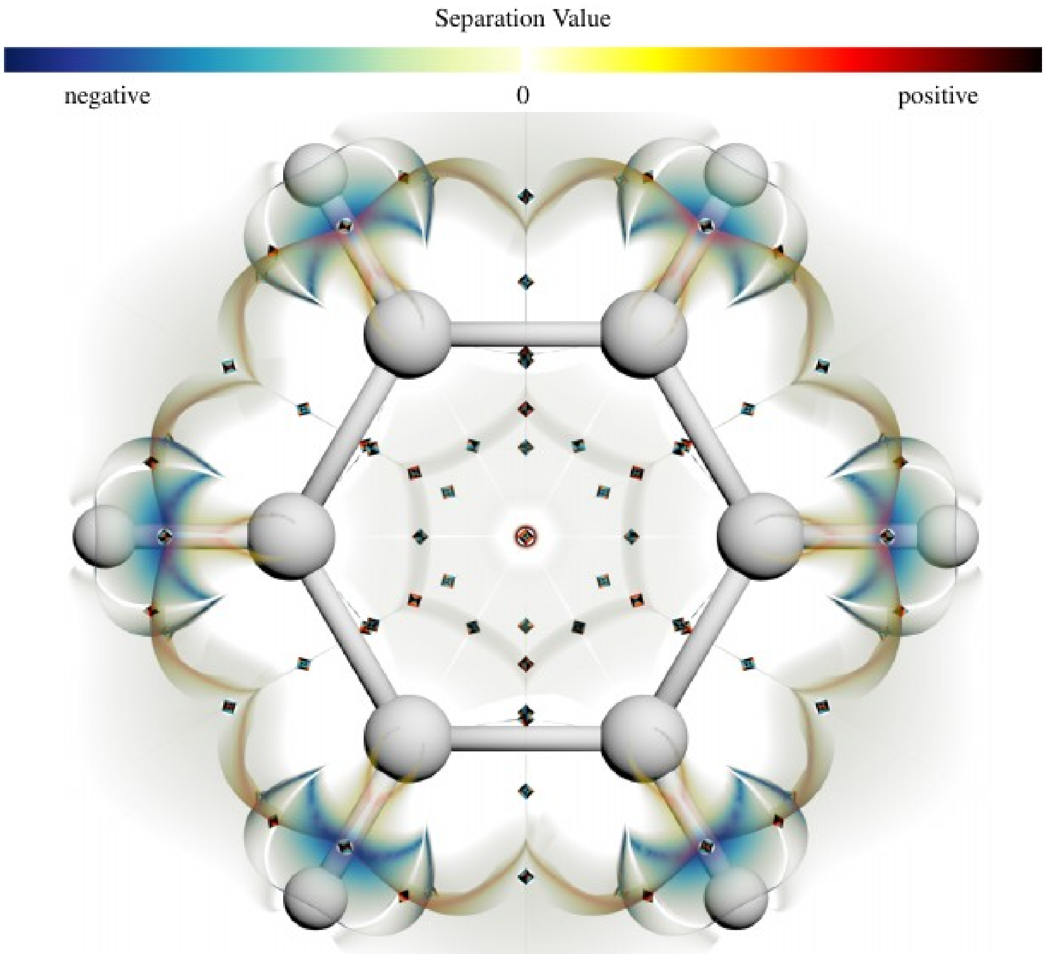


Hullin, Matthias, Reinhard Klein, Thomas Schultz, and Holger Theisel. "Finite Time Steady Vector Field Topology - Theoretical Foundation and 3D Case." The Eurographics Association, 2017. https://doi.org/10.2312/vmv.20171264.

Example



VS



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Conclusion

Summary

- LIC – overview, easy to understand
- Feature-based – when you know what you're looking for
- Topology – hybrid method, good for feature tracking

Reading

- Hullin, Matthias, Reinhard Klein, Thomas Schultz, and Holger Theisel. “Finite Time Steady Vector Field Topology - Theoretical Foundation and 3D Case.” The Eurographics Association, 2017. https://doi.org/10.2312/vmv.20171264.
- Han, Jun, Jun Tao, and Chaoli Wang. “FlowNet: A Deep Learning Framework for Clustering and Selection of Streamlines and Stream Surfaces.” IEEE Transactions on Visualization and Computer Graphics, 2018, 1–1. https://doi.org/10.1109/TVCG.2018.2880207.
- Hong, Fan, Chufan Lai, Hanqi Guo, Enya Shen, Xiaoru Yuan, and Sikun Li. “FLDA: Latent Dirichlet Allocation Based Unsteady Flow Analysis.” IEEE Transactions on Visualization and Computer Graphics 20, no. 12 (December 2014): 2545–54. https://doi.org/10.1109/TVCG.2014.2346416.
- Theisel, H., T. Weinkauf, H.-C. Hege, and H.-P. Seidel. “Stream Line and Path Line Oriented Topology for 2D Time-Dependent Vector Fields.” In IEEE Visualization 2004, 321–28, 2004. https://doi.org/10.1109/VISUAL.2004.99.
- Laramee, Robert S., Helwig Hauser, Lingxiao Zhao, and Frits H. Post. “Topology-Based Flow Visualization, The State of the Art.” In Topology-Based Methods in Visualization, edited by Helwig Hauser, Hans Hagen, and Holger Theisel, 1–19. Mathematics and Visualization. Berlin, Heidelberg: Springer, 2007. https://doi.org/10.1007/978-3-540-70823-0_1.