ETH
Eidgenössische Technische Hochschule Zürich
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Scientific Visualization

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Practical Exercise 2 - Flow Topology Analysis

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1. Introduction

In the previous exercise we located the stationary points of the velocity vector field. In this exercise we want to extend the module for analyzing and visualizing their type. As described in the lecture, this is done on the basis of the eigenvalues/eigenvectors of the velocity gradient (the Jacobian).

2. Critical Point Analysis 10 Points

Download the framework from the course web page. This is mainly the sample solution to the previous exercise with some additions. Only one function has to be implemented for this exercise: `generateGlyph`. The gradient computation and eigenvalue/eigenvector computation is already implemented.

Two functions for generating the glyphs are provided: `generateQuad` generates a quadrangle, either transparent (constructed from lines) or opaque (a polygon). This can be used to visualize the 2D manifold of 3D saddles. The other function `generateLine` generates a line and can be used to visualize the 1D manifold of the 3D saddles. Feel free to customize and extend these functions. Both functions take a scalar color parameter.

This scalar can later be mapped to colors inside Paraview by going to the "Display" tab of the FlowTopo module and selecting "Point Colors" for "Color". To reduce z-buffer problems when the line of a 1D manifold almost coincides with the 2D manifold, set "Line width = 2" for "Display Style".

Codification

Visualize the flow direction along the 1D manifold of the saddles, e.g. by using color, red (high scalar) meaning outflow along the 1D manifold and blue (low scalar) meaning inflow along the 1D manifold.

Visualize the characteristics of the 2D manifold, e.g. by color, orange (medium high scalar) for the case of complex eigenvalues (spiral case) and light blue (medium low scalar) for the case of real eigenvalues of the 2D manifold.

This way, the following four cases are handled: 1:2 saddle, 2:1 saddle, 1:2 spiral saddle, and 2:1 spiral saddle. However, the (spiral) source and sink cases are not handled. Handling and visualizing these cases is facultative.

Instead of simply drawing the 1D and 2D manifolds at constant size (GlyphRadius), you can use the corresponding eigenvalues, scaled by the GlyphRadius. In the case where all eigenvalues are real, this is possible for the 1D manifold (the eigenvector is represented by a line) and the 2D manifold (the two other eigenvectors are represented by the diagonals of the quadrangle). In the case where two eigenvalues are complex, generate a square instead of a quadrangle for the 2D manifold, scaled by the real part of the complex eigenvalues (accessible as `eigenvalues[1]`). Two orthogonal vectors lying in the 2D manifold can be computed from the normal of the complex eigenplane, as shown by the code snippet. Use the `NormalizeGlyph` parameter to allow the user to switch between the constant size mode and the mode where the eigenvalues are used for sizing.

For improving the visualization, you could generate an octagon or circle instead of a quad in the case of complex eigenvalues to prevent interpretation of the square diagonals as eigenvectors (since the diagonals are simply chosen as two orthogonal lines lying in the complex eigenplane).

Visualization

Apply your module to the isabel dataset. Add streamlines for selected critical points, e.g. the critical point at (-53.9914, -168.388, 6384.2). This can be done as follows:

- Select the Isabel dataset inside the "Selection Window"
- Instantiate the *StreamTracer* filter
- Enter the position of the critical point into the "Point Widget"
- Set "Radius" to e.g. 0.01
- Set "Number of Points" to e.g. 20
- Set "Init. Step Len." to e.g. 0.01
- "Accept"
- Go to the "Display" tab
- Select "Point IntegrationTime" for "Color by"
- If necessary, hit "Reset Range"
- At the "Parameters" tab you can try out different "Integration Directions" for getting a better impression of the flow
- You may also need to adapt "Max. Propagation" and "Max. Steps"

Verify if the streamlines follow your glyphs near the critical points. Add additional visualizations where appropriate. Finally generate at least one image and send it together with an image description containing e.g. the meaning of colors and possible interpretations to sadlo@inf.ethz.ch.