Surface Flow Visualization Using the Closest Point Embedding

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Introduction

We introduce a novel flow visualization technique for arbitrary surfaces. This new technique utilizes the closest point embedding to parameterize the surface, which allows for accurate particle advection on the surface as well as supports the unsteady flow line integral convolution (UFLIC) technique on the surface. This global approach is faster than previous parameterization techniques and prevents the visual artifacts associated with image-based approaches. Our approach is similar to the closest point method, a simple parameterizing technique for solving PDEs on embedded surfaces. By using the closest point embedding, parameterizing the surface can be done at near interactive rates and generating the LIC can be done at interactive rates, allowing flow visualization without the drawbacks of previous methods.

Method

Initially, a closest point embedding is constructed from a triangular mesh with a velocity field at the vertices. A closest point embedding stores the location on the surface that is nearest to the cell. For our implementation, a hierarchical grid is constructed to store the closest point embedding. The grid has two levels, a coarse level and a fine.

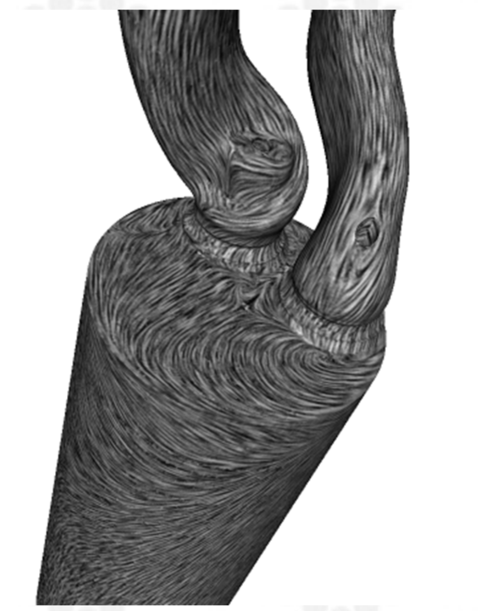
Once the triangular mesh is reconstructed into a closest point embedding, a new reprojection step is required to use the closest point embedding to place particles back on the surface after the advection method. A WENO interpolant is used to place the particles back onto the surface.

To visualize the surface flow, an unsteady flow line integral convolution (UFLIC) is applied to the closest point embedding. Given a velocity field size, a noise field is generated with a higher resolution and at the center of each voxel a particle is placed. Each particle is then advected through the field and the value at the particle's origin is deposited onto the field. Once all the particles have been advected and deposited their values along their pathlines, the values are normalized and a high pass filter is applied to the field and the result is visualized. To prepare for the next iteration, the field is subsequently jittered.

Results

For our results, we tested three datasets: an airliner, an I.C.E. train, and cylinder combustion. Here is the airliner dataset. To build the closest point embedding and the refined grid took 0.17 seconds while applying the UFLIC took 0.12 seconds. Next is the cylinder combustion dataset. This dataset has input and exhaust pipes as well as valves inside the combustion chamber. There is a swirling flow which lines up with the center of the cylinder and can be seen on the surface. To build the closest point grid and the refined grid took 0.28 seconds, while applying the UFLIC to the surface took 0.17 seconds. Finally, the ICE train is a simulation of a high speed train traveling at 250km/hr with wind blowing at a 30 degree angle. The wind creates a drop in pressure, generating separation and attachment flow patterns. In this dataset, building the closest point grid and the refined grid to 0.04 seconds, while applying the unsteady flow LIC took 0.1 seconds.

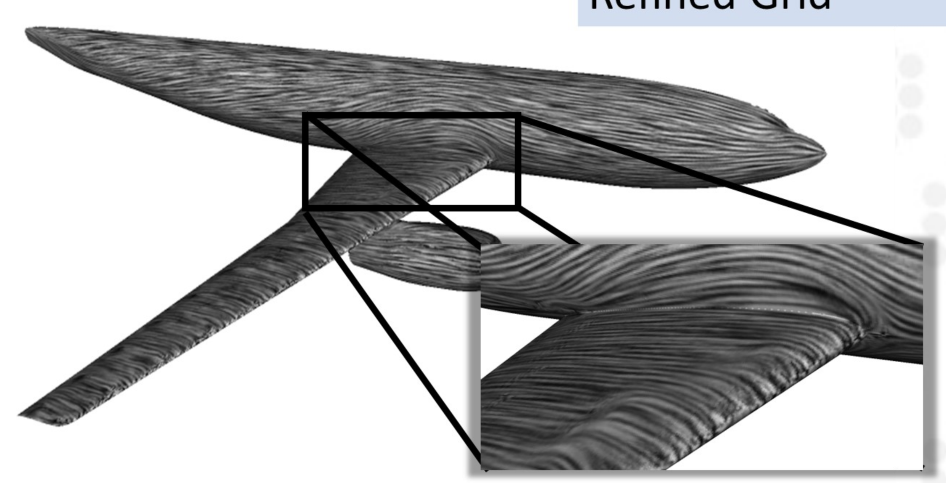
Closet Point Grid	144x222x472
Refined Grid	432x666x1416



Build CPG	0.07s
Build Refined Grid	0.21s
UFLIC	0.17s

Cylinder Combustion

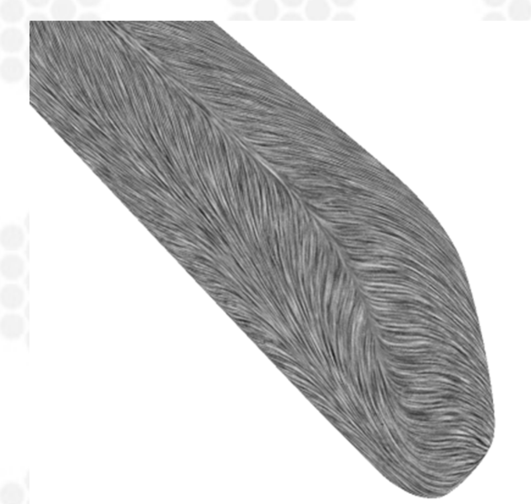
Closet Point Grid	384x191x55
Refined Grid	1536x764x220



Airliner

Build CPG	0.06s
Build Refined Grid	0.11s
UFLIC	0.12s

Closet Point Grid	512x58x69
Refined Grid	2048x232x276



Build CPM	0.03s
Build Refined Grid	0.01s
UFLIC	0.1s

ICE Train

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