A Multiresolution Streamline Seeding Plane for 3D Flow Visualization

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ABSTRACT

Flow visualization in 3D is challenging due to perceptual problems such as occlusion, lack of directional cues, lack of depth cues, and visual complexity. The challenge of 3D flow visualization is often addressed by selective streamline seeding strategies. We present the first interactive, multiresolution (MR) streamline seeding plane for 3D flow visualization. The seeding plane affords the user 6 interactive degrees of freedom (DOF): (1-3) 3 translational, (4) scaling, (5) rotation, and (6) resolution. This interactive tool provides the user with a very fine level of streamline seeding control. Combined with our other interactive 3D flow visualization features, the streamline seeding plane gives a brand new level of control to the user investigating a fluid flow field.

Keywords

3D flow visualization, vector field visualization, streamline, multiresolution streamline seeding plane, streamline seeding strategy, interaction

INTRODUCTION

Flow visualization is a topic that has rapidly increased in popularity over the past ten years. Flow visualization is useful for several disciplines including: computational fluid dynamics (CFD), aerodynamics, turbomachinery design, meteorology, climate modeling, and oceanography. As a result, the research community has proposed several flow visualization strategies to accommodate the growing demand for visualization solutions.

3D FLOW VISUALIZATION AND STREAMLINE SEEDING STRATEGIES

Flow visualization in 3D, as opposed to 2D or on surfaces, presents its own special challenges. Perceptual problems such as occlusion, lack of directional cues, lack of depth cues, and visual complexity are acute in 3D.

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Also, data set sizes for 3D flow are of unprecedented size, especially in the case of unsteady (time-dependent) flows. To date, no solution has been presented which allows the visualization of a complete, unsteady, 3D vector field at interactive frame rates. Therefore 3D flow visualization strategies usually focus on a subset of the vector field.

One means by which to focus on a particular subset, area of interest, or feature of a flow field is via a streamline seeding strategy. In general, streamline seeding strategies can be classified into 3 categories: (1) *image-based*, or geometric, seeding strategies such as the evenly spaced-streamline seeding strategy presented by Jobard and Lefer [2], (2) *topological*, or feature-based, seeding strategies such as those presented by Verma et al. [6] or Sanna et al. [4], or (3) *interactive* seeding strategies using a streamline seeding rake used by Bryson and Levit [1] or Schultz et al. [5]. Our method falls into the third category–an interactive streamline seeding strategy.

A MULTIRESOLUTION STREAMLINE SEEDING PLANE

A schematic of the MR streamline seeding plane is shown in Figure 1. This tool provides the user with 6 interactive DOFs: (1-3) 3 translational, (4) scaling, (5) rotational, and (6) resolution control. The design of the seeding plane is inspired by the fluid flow fields resulting from CFD simulations. These 6 interactive DOFs are required by engineers investigating the results of CFD simulations because the meshes from CFD embrace a wide variety of components, features, and levels of resolution. Ideally, the tools used to analyze and visualize these data sets should be flexible enough to adapt their *size*, *orientation*, and *resolution* to fit the features of interest either automatically or through user-specified parameters.

For the design, we started with a the classic 1D streamline seeding rake and added the options of a user-specified scaling parameter and number of rake prongs. Allowing the user to specify the number of $seeds/meter$ turns the conventional rake into a multiresolution rake. Then, we extend this by allowing the user to specify the number of *rake prong stacks* or parallel rakes. The result is an MR seeding plane where the resolution is specified in $seeds/m^2$ (Fig. 1).

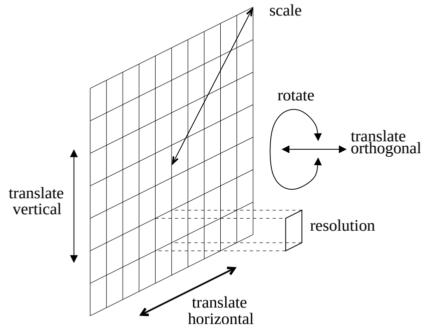

Figure 1: The multiresolution seeding plane has 6 interactive DOFs: (1-3) 3 translational, (4) scaling, (5) rotation, and (6) resolution

INTERACTION

The user interaction starts off with the user specifying the initial location of the rake at an arbitrary position in 3D space via a mouse click. Once the initial position has been specified, the user may click and drag the seeding plane in arbitrary direction and the resulting streamlines are updated automatically. The user also has the options of rotating the seeding plane about its center, scaling the plane, and specifying the resolution of the seeds via the number of rake prongs and rake prong stacks (i.e., rows and columns). The user also has the option of specifying a plane of orientation, i.e., if the user may specify the seeding plane to be aligned with one of the XY, XZ, or YZ coordinate planes. Also, the user may specify multiple instances of MR seeding planes as illustrated in Figure 2 Several other visualization options, such as turning on a wire-frame or semi-transparent CFD mesh context, are describe in more detail by Laramee [3].

RESULTS AND CONCLUSION [1]

Frame rates depend on both the size of the seeding plane and the length of the streamlines –the user may also specify a maximum geometric length for the streamlines. Interactive frame rates of 11-12 *fps* for 3×3 planes to 0.5-0.6 *fps* for 10×10 planes are typical. We believe that the added level of user control and interaction provided by the MR streamline seeding plane is a very useful tool for 3D flow visualization. This tool gives a brand new level of control over to users investigating the flow field.

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[1] supplementary animations of the MR seeding plane can be found at `http://www.winslam.com/rlaramee/seedingPlane/`

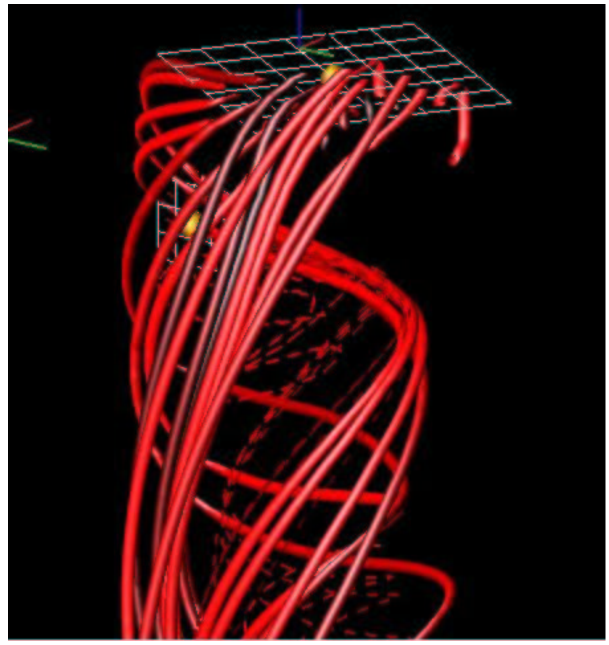

Figure 2: This image shows 2 MR streamline seeding planes: One in the foreground with streamlines rendered as tubes and one in the background with streamlines rendered as dashes.

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