Interactive 3D Flow Visualization Using a Streamrunner

Robert S Laramee
VRVis, Reseach Center for Virtual Reality and Visualization
Donau-City-Strasse 1
A-1220 Wien, Austria
laramee@vrvis.at
www.vrvis.at

May 1, 2002

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. In this paper we present an interaction technique that addresses these special problems for 3D flow visualization. The feature we present, a streamrunner, gives the user interactive control over the evolution of streamlines from the time they are seeds until they reach their full length. The interactive streamrunner control minimizes occlusion and visual complexity and maximizes directional and depth cues for 3D flow visualization. Combined with our other interactive 3D flow visualization tools, the streamrunner gives a brand new level of control to the user investigating the vector field.

Keywords

3D flow visualization, 3D vector field visualization, streamlines, streamrunner, interaction, occlusion, visual complexity

1 Introduction

Flow visualization computing is a topic that has rapidly increased in popularity over the past several years. Applications of flow visualization include visualization of computational fluid dynamics (CFD) data, visualization of flow in turbomachinery design, flow visualization for shock wave phenomena, and visualization of weather patterns, to name just a few. As a result, many techniques for vector field visualization have been the topic of research including: hedgehog visualization, streamlines and streamtubes, dimensional reduction techniques such as cutting or slicing, animation of steady and unsteady flow, vector field clustering, and multiresolution & adaptive resolution visualization techniques.

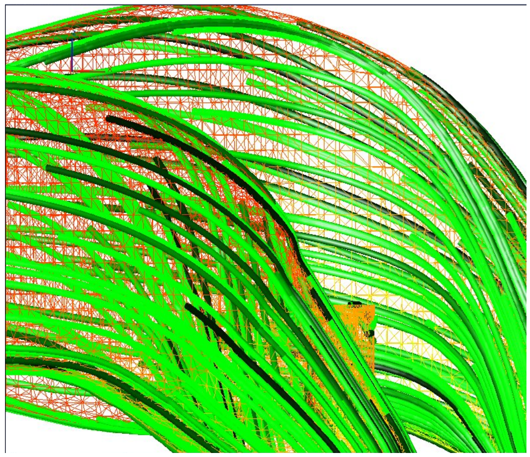

Figure 1: This image illustrates some problems with 3D flow visualization including occlusion, over-complexity, and lack of directional cues.

2 Flow Visualization With Streamlines

Of the different tools used to visualize flow, streamlines are a very popular choice due to their intuitive semantics and ease of implementation. The body of literature related to streamlines is vast including: streamline rendering algorithms [Zöckler et al., 1996], streamline placement and spacing algorithms [Jobard and Lefer, 2000, Turk and Banks, 1996], streamline illumination [Zöckler et al., 1996], and streamline animation for unsteady flow [Jobard and Lefer, 2000]. Streamlines can be useful in engineering because engineers are often interested in minimizing the number of vortices in a fluid flow field.

3 Related Work in 3D Flow Visualization

The majority of flow visualization research literature is concerning 2D visualization techniques. This is in part because flow visualization in 3D presents additional challenges such as occlusion, lack of directional cues, lack of depth cues, and visual complexity. Figure 1 illustrates these problems in the context of a CFD emissions model. Fuhrmann and Gröller [Fuhrmann and Gröller, 1998] use dashtubes with volume filling properties, reduced occlusion, animation of flow for clear direction, and fast rendering. However, complexity of the flow field and lack of user control are still problems in the visualization. Rezk-Salama et al [Rezk-Salama et al., 1999] present an interactive technique for 3D flow visualization using LIC in combination with 3D texture mapping. However, their method results in an over complex 3D flow visualization as well as occlusion. Zökler et al [Zöckler et al., 1996] present interactive 3D flow visualization with real-time illuminated streamlines. However, their method suffers from occlusion and visual complexity.

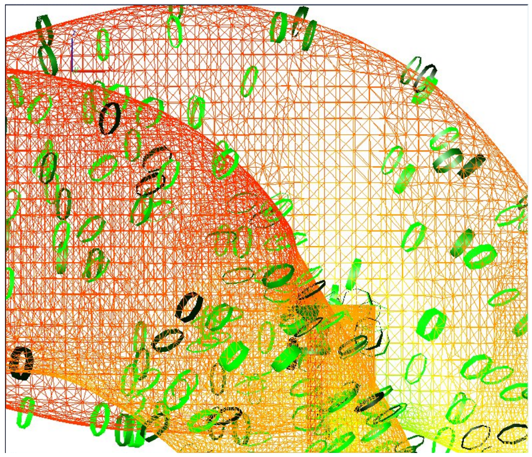

Figure 2: This image shows stream seeds as short pipe segments including a wire frame CFD emission model as context information. In this way occlusion and image complexity are minimized.

4 A Streamrunner

The streamrunner feature addresses the problems of occlusion and scene complexity directly by giving the user interactive control over the evolution of streamlines from the time they are seeds until they reach their maximum length. A streamline may terminate when it reaches a boundary in the geometry, reaches a vortex, or reaches a maximum length set by the user.

Using the streamrunner, the user is able to set the stream evolution to time step 1 as shown in Figure 2. At this point in time, only the streamline seeds are shown. Individual streamlines are easily distinguished and focused upon early in their evolution because occlusion has been almost completely eliminated while complexity is at a minimum. The streamrunner can then be used to change the current time step of the flow scene such that the user can watch the streamlines grow, or run, in the direction of the flow. This gives a clear indication of flow direction. With the streamrunner, the user is able to focus on an individual streamine, a group of streamlines, or a particular area of the flow field as they interactively adjust the scene's time step. Watching the streams flow combined with illumination and shading, in our case using tubes, also gives added depth cues.

5 Other Features

We combine the streamrunner feature with other classic interaction techniques such as rotation, scaling, and focus and context information so the user maximizes their understanding of the vector field. In addition to the streamline features of shading and running, the user may also (1) choose a non-uniform coloring scheme so colliding streamlines can be distinguished, (2) turn on or off semi-transparent or wire frame context information, (3) animate the streams to move in the direction of the flow as well as interactively adjusting the animation speed, (4) interactively adjust the streamline seeding density in the flow field, and (5) interactively adjust the streamline width, or streamtube diameter. The streamrunner also allows the user to trace the evolution of the streamlines *backwards* in order to see where a streamline has come from.

6 Conclusion

We believe that the added interaction provided by the streamrunner is a very useful tool for 3D flow visualization. In fact, this feature was requested by the head of business development in a real-life automotive simulation software development department. The streamrunner gives a brand new level of control over to users investigating a vector field.

7 Acknowledgements

We would like to thank all those who have contributed to the finance of this research including AVL (`www.avl.com`) and the Austrian Governmental research program called KPlus (`www.kplus.at`). We would like to thank Zoltan Konyha of VRVis and Dr Hans Peter Blahowsky and Mark Mitterdorfer of AVL for their valuable contributions and feedback. And finally we would like to thank Helwig Hauser for helping us to prepare the final document.

References

[Fuhrmann and Gröller, 1998] Fuhrmann, A. L. and Gröller, E. (1998). Real-time techniques for 3D flow visualization. In Ebert, D., Hagen, H., and Rushmeier, H., editors, *IEEE Visualization '98*, pages 305–312. IEEE.

[Jobard and Lefer, 2000] Jobard, B. and Lefer, W. (2000). Unsteady flow visualization by animating evenly-spaced streamlines. In Gross, M. and Hopgood, F. R. A., editors, *Computer Graphics Proceedings (Eurographics 2000)*, volume 19(3).

[Rezk-Salama et al., 1999] Rezk-Salama, C., Hastreiter, P., Christian, T., and Ertl, T. (1999). Interactive exploration of volume line integral convolution based on 3D-texture mapping. In Ebert, D., Gross, M., and Hamann, B., editors, *IEEE Visualization '99*, pages 233–240, San Francisco. IEEE.

[Turk and Banks, 1996] Turk, G. and Banks, D. (1996). Image-guided streamline placement. In Rushmeier, H., editor, *SIGGRAPH 96 Conference Proceedings*, Annual Conference Series, pages 453–460. ACM SIGGRAPH, Addison Wesley. held in New Orleans, Louisiana, 04-09 August 1996.

[Zöckler et al., 1996] Zöckler, M., Stalling, D., and Hege, H.-C. (1996). Interactive visualization of 3D-vector fields using illuminated streamlines. In *Proceedings of IEEE Visualization '96, San Francisco*, pages 107–113.