Investigative Tools for Arterial Flow in the CAVE

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Introduction

Our goal was to create a simple environment that encouraged investigation of data. The improved program provides users with more options for viewing data by introducing two progressively detailed levels of visualizing flow information. In addition to the existing overall level of visualization, in which data is sampled throughout the entire artery, users can further investigate data within a region of interest or query quantitative data at specific points. Our additions were based on our own reactions to the current artery model as well as input from professor-scientist Peter Richardson of Brown University.

Artery Visuals & Overall View

We found the mesh pattern in the original artery to be distracting, so our prototype includes solid colored, transparent walls. Because fluid flow is considered the most important data in the artery, we chose low to mid-saturation purple artery walls to provide a subtle contrast to the more saturated velocity icons, which range from yellow to green based on speed (green is the fastest). We also wanted to use the artery walls to convey useful data, so we mapped wall pressure to subtle variations in saturation.

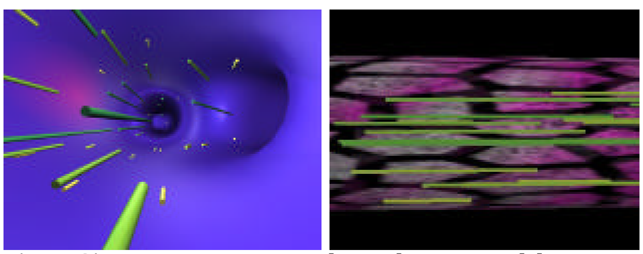

Fig. 1: Cinema4D prototype and actual artery model

We quickly realized that the lack of a texture combined with the lack of lighting in the artery model caused us to lose a sense of depth. By using a more subtle texture than that of the original model, we regained depth cues with minimal complexity. Due to the graying-out effect of the CAVE on the wall and icon colors, the slow velocity icons also did not stand out as much as they did in our prototype. In the future, I would choose a more blue-hued purple color for the wall and have faster velocity icons be shaded with a blue-toned green to blend into the artery wall. I would also play with line thickness to emphasize the different velocity values and compensate for the fact that the more interesting flow (slow flow) is less visible because of its shorter length: faster icons could be drawn thinner compared to "fatter" low-velocity icons. Although I had never really considered how the wall pressure would vary with a real data set, the saturation changes in wall color confirmed the fact that artery pressure is much lower after flow passes the bifurcation.

Selective Focus Tools

One of the tools that we developed for users to study data within a region of interest is the Cross-section Tool. Inspired by the use of cross-sections as investigative tools in other fields of science (such as medicine and geology), we designed this tool as to be a plane that intersects the artery at a perpendicular angle; color changes within the plane would be mapped to changing data values. Although we originally planned for this plane to be transparent so that users could see where cross-section lies within the artery, the complex information on the cross-section was difficult to discern because of the transparency and varying wall pressure values mapped to the artery wall. As illustrated in Fig.3, the opaque cross-section is best viewed from far away.

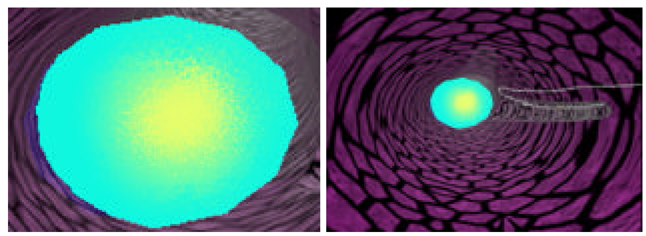

Fig. 2: Near and far view of Cross-section Tool

The Pathline Shooter allows users to shoot a velocity icon down the artery and view it in the context of its time-elapsed pathline. We hoped that the tool would capture pathline anomalies (i.e. where flow begins to go down the bifurcation, starts to come back out, then turns around and heads back down the bifurcation). Although Fig. 3 illustrates how this was successfully achieved, we realized through our own testing how difficult it is to reproduce this anomaly since it requires a few test "shots" in that region. Unless they were expecting this pathline phenomena after observing the velocity icons at an overall level, first-time users would probably only discover this anomaly by chance. This could be improved in future versions of the artery program by implementing an algorithm that checks each pathline for rapid changes in velocity direction and displaying "suspicious" pathlines that qualify under this criteria.

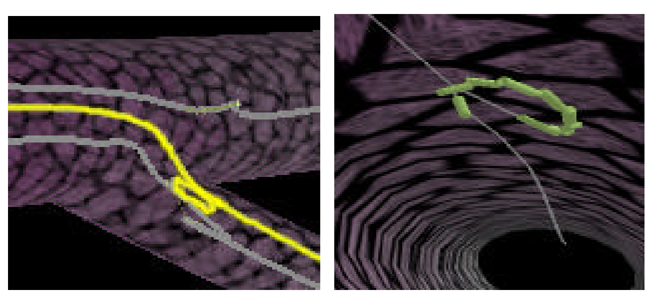

Fig. 3: Outside and inside view of pathline anomaly (highlighted in yellow in left panel) in actual model

Point Sampling and Quantitative Data

The Quantitative Tool allows users to explore data at the most detailed level possible. Users can more accurately compare data at different locations, as well as study the effect of time on data and the relationship between data of different types (i.e. velocity vs. pressure).

With this additional tool, users can place up to two probes anywhere in the artery and view the numerical data as well as the cyclical changes in data over time. In addition to confirming fluid flow basics that we had learned in the class (i.e. that flow velocity gets progressively slower until it is almost zero at the walls), I was surprised to learn that significant velocity changes at multiple locations did not necessarily imply proportionate pressure differences.

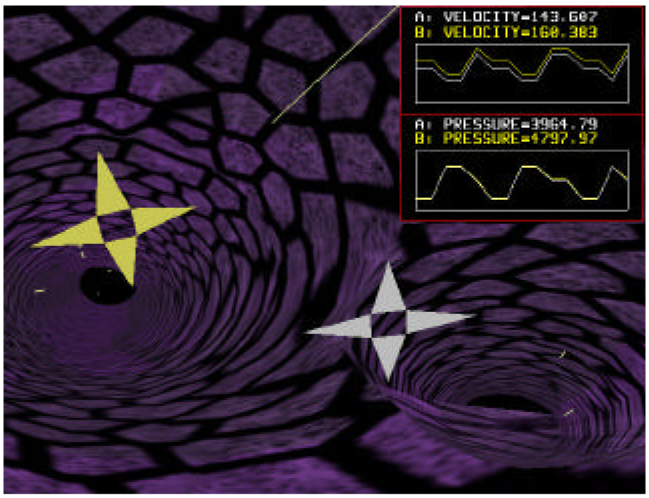

Fig. 4: Actual Quantitative Tool

Conclusion

Although the present artery model is successful in conveying general anomalies in fluid flow at a bifurcation, our improved version provides users with more tools to explore these areas of interest. While most of our study this semester focused on aesthetic issues of scientific visualization and influenced our own visual choices, we fear that an artery program lacking the necessary tools for in-depth investigation will not be taken seriously by those seeking to use the program to solve this complex problem of arterial fluid flow at a bifurcation. As fluid flow novices, we have solidified basic flow concepts learned in class as well as gained useful insight regarding this particular issue through repeated use of the tools that we've developed. It is now imperative that a formal study be explored to evaluate their actual usefulness to the scientific and educational community. These investigative tools were also designed to be scalable and extendable, and we hope that they can be used in other CAVE projects such as the Mars topography project and future visualizations.