CS 530 HMWK 3

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November 5th, 2013

The motivation for this visualization project is to show good techniques to visualize the vector (direction and magnitude) information that is provided. This is similar to many CFD datasets [1], and can be an insightful way to provide data about flows. The methods of glyphs, streamlines and streamsurfaces, and finally the pairing of vector and scalar data is analyzed and visualized. Through all of the visualizations, a dummy of the geometry of the wing is provided for visual context and better understanding of the conditions creating the vorticity displayed.

[1] R. B. Bird, W. E. Stewart, and E. N. Lightfoot. *Transport Phenomena*. John Wiley & Sons, Inc., New York, NY, 2nd edition, 2007

Task 1 - Glyphs

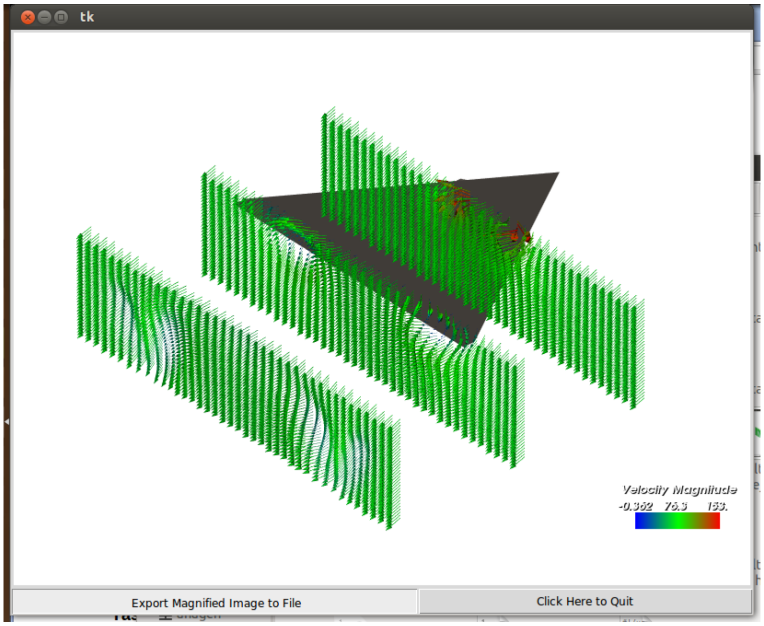
For vector datasets glyphs are an unfavored and even antiquated way to represent data. This is due to the occlusion, clutter, and difficulty in choices of seeds. In order to show these pitfalls, but also to explore the data set, a glyph image of a downsampled data set of air velocity was visualized. It is recommended that only low resolution data sets be used for this visualizer, as the downsampling method was created for use with the `tdelta-low.vtk` dataset.

Because of the requirement of using this method with low resolution datasets, please use only

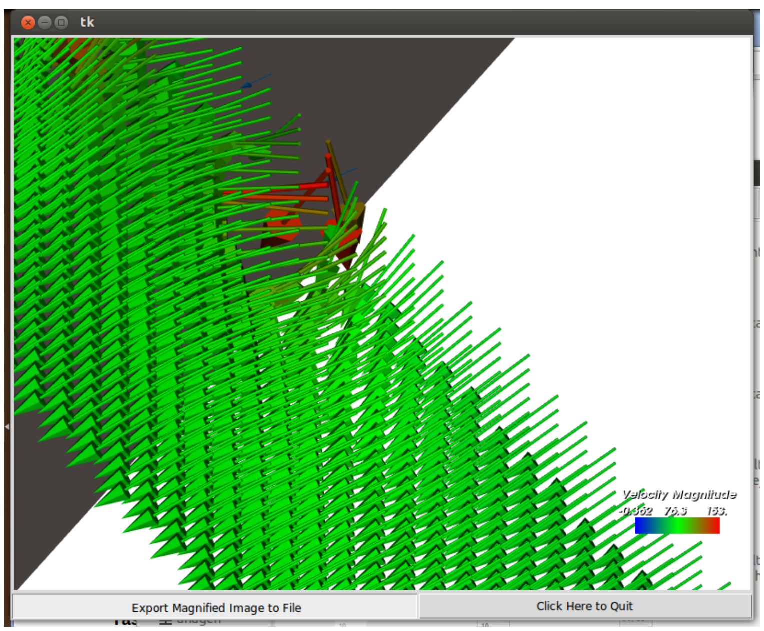
```
$vtkpython
>>> three_planes.py \
    tdelta-low.vtk \
    tdelta-wing.vtk
```

The images provided in Figure 1 illustrate these pitfalls, but also show how quickly an understanding can be created by using glyphs. The Subfigure 1a shows the evolution of a small point of high velocity close to the wing that then tracks back to a larger point of low velocity at the back of the wing, which is finally tracked into a vee of low velocity separated downwards in the wake of the wing. While the image does provide intuitiveness such as this, the downfall is illustrated well by Subfigure 1b, which shows the clutter and occlusion present when looking close-up on the area of high velocity. It is difficult to obtain any idea of the true behavior of the vectors at this point. Also, with any rotation of the view, the other planes start to clutter the visualization even more. Certainly, glyphs can provide a first cut description of data set behavior, but they lack the elegance and robustness to be a good visualization technique.

Figure 1: Glyph Rendering of CFD Velocity Vector Data Set



(a) Full Dataset (**Link to Hi-Resolution**)



(b) Recirculation Bubbles (**Link to Hi-Resolution**)

Task 2 - Streamlines, Stream Tubes and Stream Surfaces

The downfalls shown by glyps can be alleviated with the thoughtful and correct seeding of streamlines. These streamlines can be supplemented by adding three dimensional understanding to them. This can be done by creating tubes, which will add shading to help the visual system understand their three dimensional nature, but comes at the expense of requiring a reduction in resolution (because the tubes take up more physical space). Creating stream surfaces can add the shading that is required for the visual system to understand the three dimensional nature of the system without requiring lowered resolution.

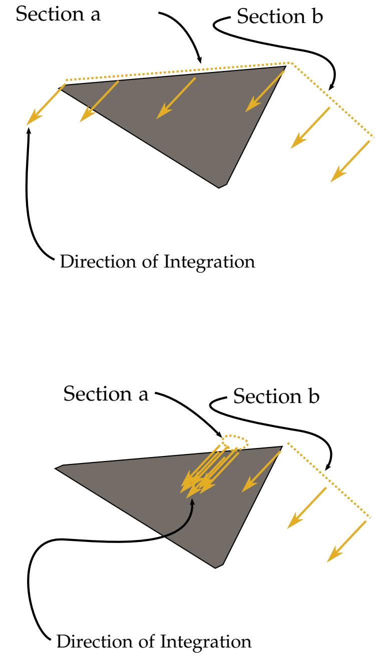


Figure 2: Seeding Methodologies (Used and Proposed)

Three visualizations were created, one with a high density of stream lines, the other with a lowered density of stream tubes, and finally one with a well sampled stream surface. The seeding was performed using the first methodology presented in Figure 2. A streamline following the edge of the wing gave a very good representation of the vortices (because air from directly in front of the wing is sucked into the vortex). This is represented by Section A of the used streamline rake. A streamline from the front of the dataset shows effectively how a layer of air is pushed away from the wing and does not enter the vortex region, this is represented by Section B of the used streamline rake. In Figure 2, a secondary proposed method for seeding is given, which was designed in hindsight to further accentuate the vortex.

Figures 3, 4, and 5 show the results of the three renderings. The colormap was chosen using typical ANSYS jet coloring [2], and with a limited range to show the variations in velocity better. The streamline rendering provides little three dimensional context, but the streamtube and streamsurface rendering provide very good results. The streamsurface rendering exhibits tearing in the vortex region, as expected, and thus has some split streamers near the end.

[2] R. B. Bird, W. E. Stewart, and E. N. Lightfoot. *Transport Phenomena*. John Wiley & Sons, Inc., New York, NY, 2nd edition, 2007

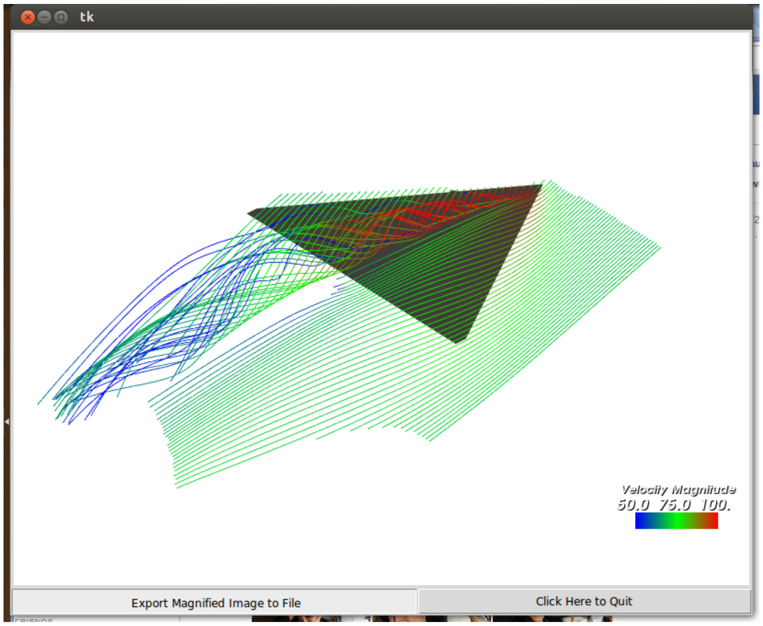


Figure 3: Streamline Rendering of CFD Velocity Vector Data Set (**Link to Hi-Resolution**)

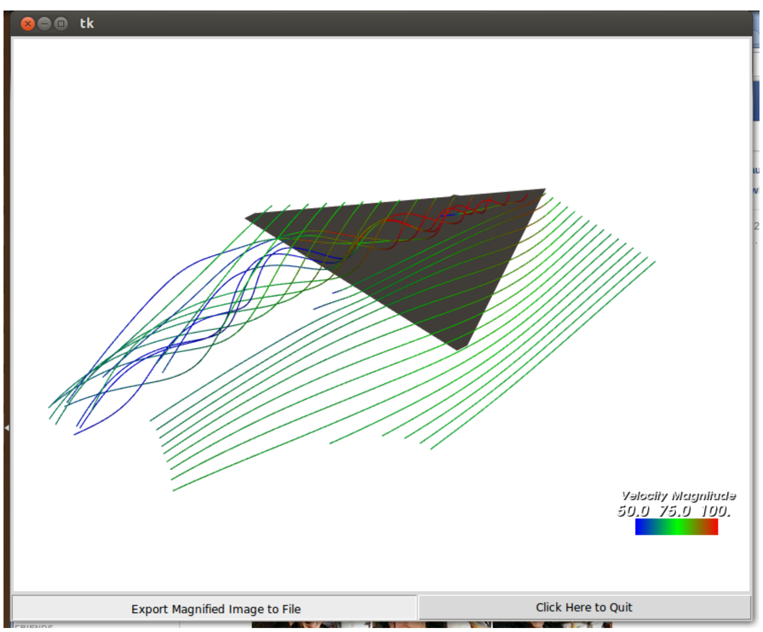


Figure 4: Streamtube Rendering of CFD Velocity Vector Data Set (**Link to Hi-Resolution**)

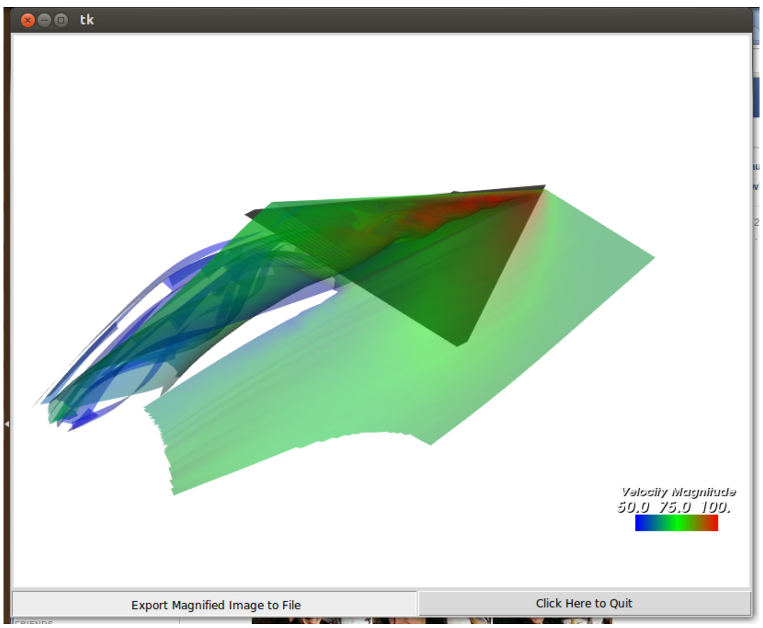


Figure 5: Streamtube Rendering of CFD Velocity Vector Data Set (**Link to Hi-Resolution**)

Task 3 - Combining Scalar and Vector Visualization

Because the interesting parts of the current dataset are the vortexes, a scalar calculation of the vorticity of the dataset can provide supplementary data to the vector visualization. In order to determine the surfaces of interest, a slider bar was used to probe the vorticity magnitude data set. When the surfaces of interest were discovered (that which corresponded to the layer of air which is pushed away from the vortex, that which corresponded to the outer surface of the vortex, and that which corresponded to the inner core of the vortex), they were then plotted with streamlines supplemented. Because of the the focus of the visualization, a rake was created which followed both sides of the wing, to provide a symmetric visualization of the air being trapped in the vortexes. This coincided perfectly to be included in between the outer and inner surfaces provided by the vorticity dataset. The final rendering shown in Figure 6 provides an example of this.

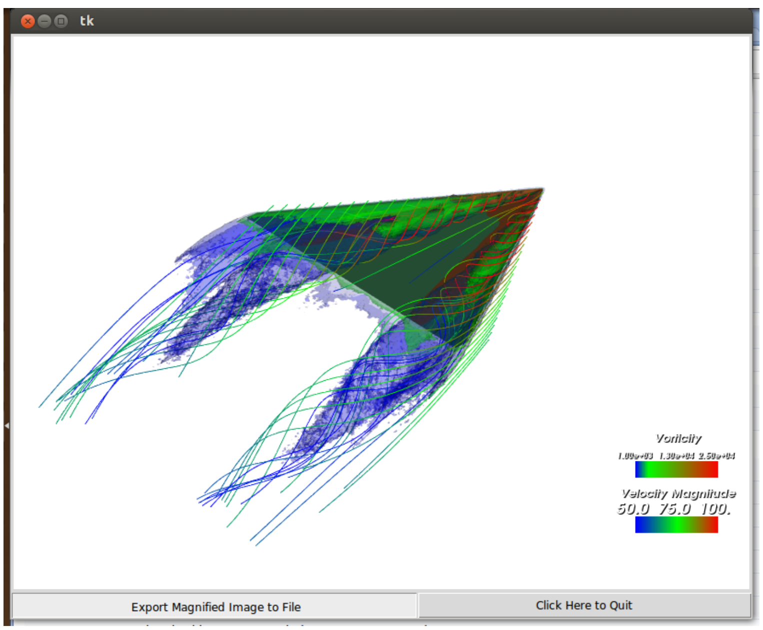


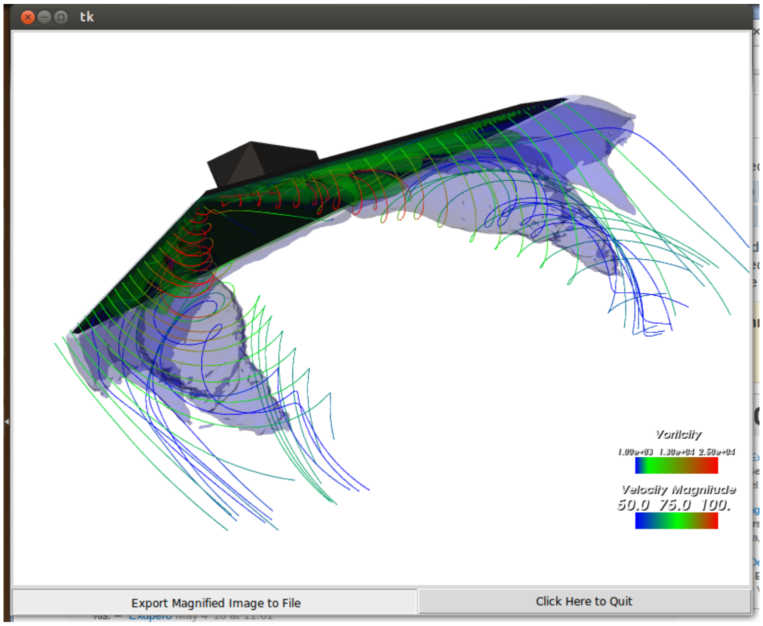
Figure 6: Combined Rendering of CFD Velocity Vector and Vorticity Scalar Data Set (**Link to Hi-Resolution**)

Task 4 - Analysis

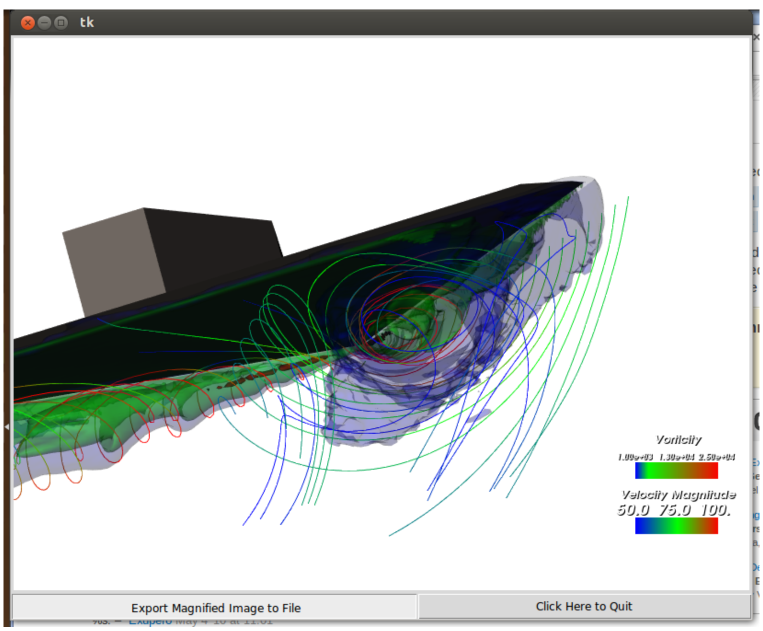
As was aptly demonstrated in Tasks 1 and 2, the use of streamlines, tubes, or surfaces is much more effective than that of glyphs. This is simply because of the removal of occlusion and the mindful seeding to avoid clutter. The benefit of the use of glyphs is the speed in which it is implemented, and also that it provides a way to probe the dataset that is in no way dependent on the data. A plane will always be indicent at that defined plane, whereas streamlines may be integrated into and out of desired spaces. This is well discussed using figures throughout Task 1 and Task 2.

In task 3, the isosurfacing added some physical understanding to the stream lines, because it became obvious the relationship between the vorticity and the velocities that air was moving. In figure 7, several more renderings show the benefits of the combination, especially in showing how the streamlines that do get encaptured in the vortex first have to enter the "outer" vorticity surface bevoer starting their vortex movement.

Figure 7: Illustration of Velocity Vector-Vorticity Scalar Relationship



(a) Front View of Velocity Entrapment in Vorticity Surfaces (**Link to Hi-Resolution**)



(b) Back View of Velocity Entrapment in Vorticity Surfaces (**Link to Hi-Resolution**)

References

[1] R. B. Bird, W. E. Stewart, and E. N. Lightfoot. *Transport Phenomena*. John Wiley & Sons, Inc., New York, NY, 2nd edition, 2007.