Assignment-4
CS 6635
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Part 1: Streamline Visualization of Air Flow above Heated Disk using Glyphs [15 pts]
I loaded the heated disk dataset. Used the the Glyph filter with Glyph type arrow, scalar factor was adjusted as per the data value, orientation and scale are chosen as vectors. Glyph mode was set to "All Points", changed the color as per vector maginitude and obtained the Fig 1. image consisting of the underlying vector filed.

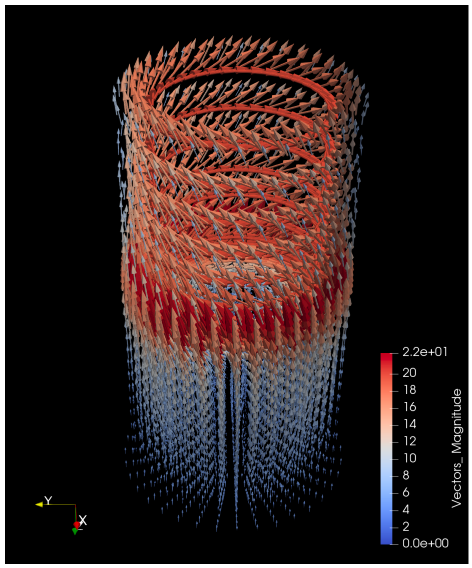

Fig 1. Glyph across the heated disk to visualize the vector field.

Applied the streamline tracer with "Point Source" as seed type and coloring as per vector magnitude to extract the streamline and also used the tubular surface for better visualization. Fig 2. Represents the streamline with tube filter.

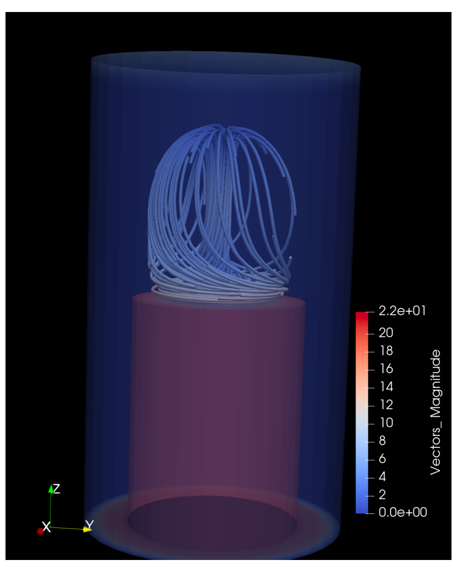

Fig 2. Represents the streamline with tube filter.

Next, I applied the Glyph filter to visualize the magnitude and direction of the flow. I choose the glyph type arrow, scale array as vectors and adjusted the scale factor and sampling with uniform spatial distribution to obtain fig 3. From fig 3. We can observe that, at the center of the disk, air is flowing upward reaches a point at the top and started flowing in the downward direction across the periphery. Afterwards, it rotates in the counterclockwise direction at the surface of the disk. As per the magnitude, the air velocity is maximum at the outer surface of the disk as represented by size of the arrow and color (light orange) of the arrow as compared to the air above the disk which has blue in color with arrow size small.

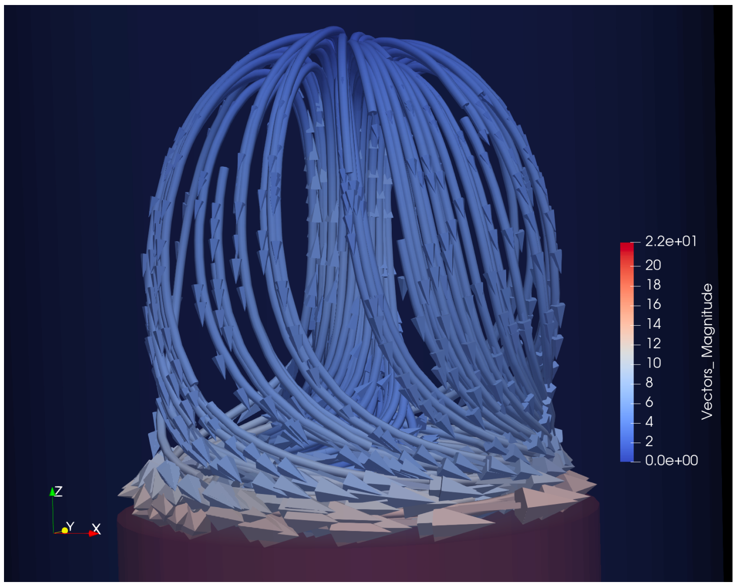

Fig 3. Glyph type arrow to visualize the direction and magnitude of flow across heated disk.

Part 2: Hurricane Katrina Visualization [25 pts]
Step1

1. We have provided with the Hurricane Katrina Dataset at a particular timestep. I applied the stream tracer filter with vectors as wind with seed type as point cloud (fig 4). I have added the color map for the speed in all the images to get a better idea of air flow direction and magnitude.

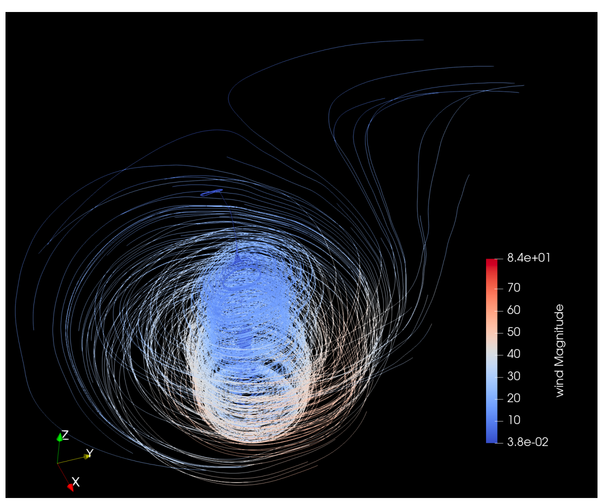

Fig 4. Streamlines of hurricane Katrina with seed type point cloud.

2. Furthermore, I applied the tube filter to enhance the visualization as shown in figure 5.

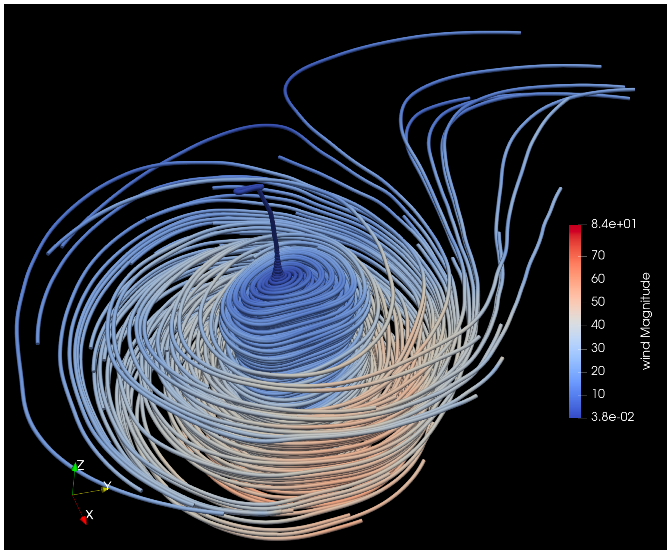

Fig 5. Streamlines of hurricane Katrina with seed type point cloud and tube filter.

3. I used the cone Glyphs with setting the orientation array and scale array as wind to visualize the wind direction and magnitude as shown in Figure 6.

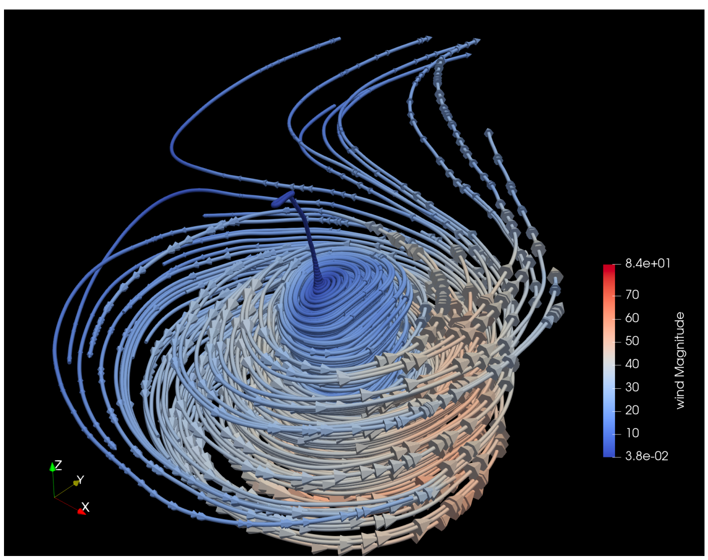

Fig 6. Cone Glyph to visualize the streamlines of hurricane Katrina

Step 1 was repeated for the line seed type. Fig 7. Represents the streamlines of hurricane Katrina with seed type line.

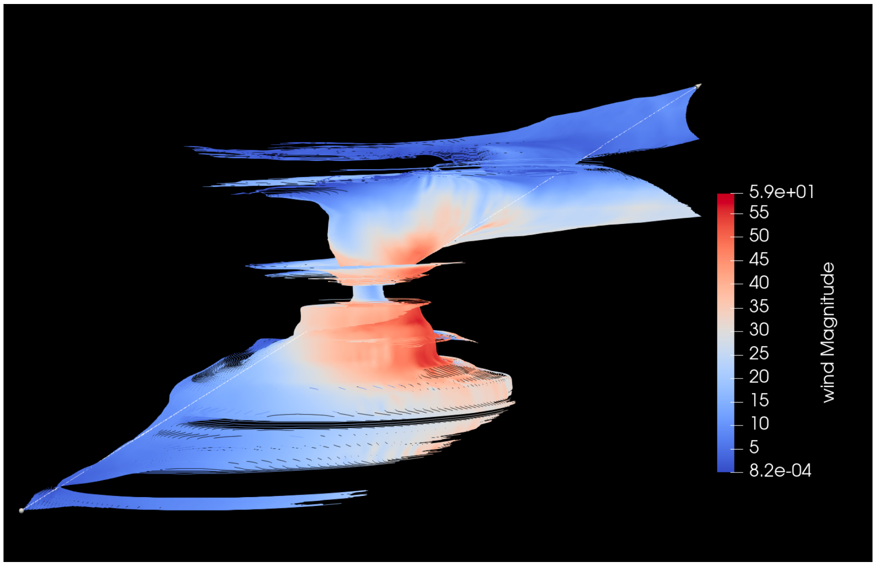

Fig 7. Streamlines of hurricane Katrina with seed type line

With tube filter, I adjusted the stream tracer resolution to visualize the tube clearly. Fig 8. Shows the streamlines with tube.

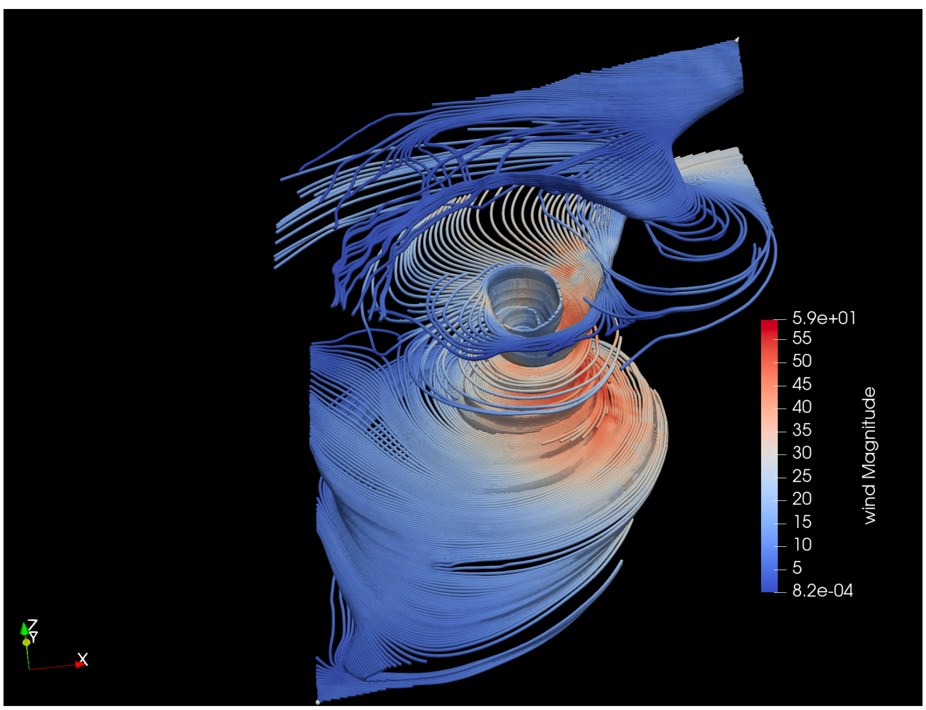

Fig 8. Streamlines of hurricane Katrina with seed type line with tube.

Applied the cone glyph and adjusted the resolution to capture the magnitude and direction of air flow.

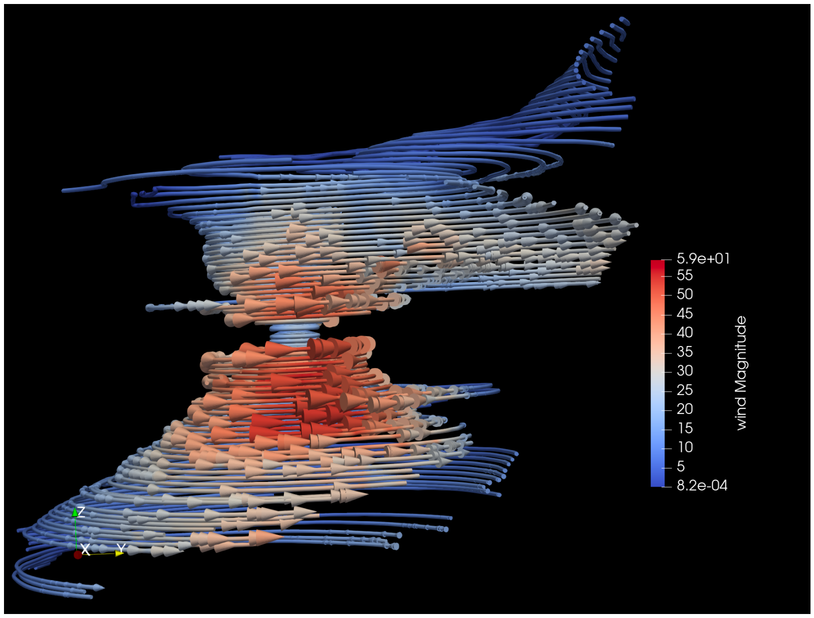

Fig 9. Cone Glyph hurricane Katrina.

From these above images, it can be inferred that near the eye of the hurricane the wind velocity is maximum colored by red and with bigger cone size and top and bottom the velocity is low. Furthermore, the direction of wind flow is in counterclockwise direction.

Step 2:

4. Create the visualization with arrow glyph with sampled places throughout the volume.
5. Scaled the vectors proportion to their speed and added a colormap for the speed.

Figure 10. represents the arrow Glyph with seed type point cloud to visualize hurricane Katrina. Fig 11. arrow Glyph with seed type line and fig 12. shows arrow Glyph with seed type line. The streamline with glyph helps to visualize the different features of the hurricane. It helps in understanding the wind flow direction and magnitude. The visualization also shows how the diameter of the cone changes at particular time step and how the flow diverges out from the center.

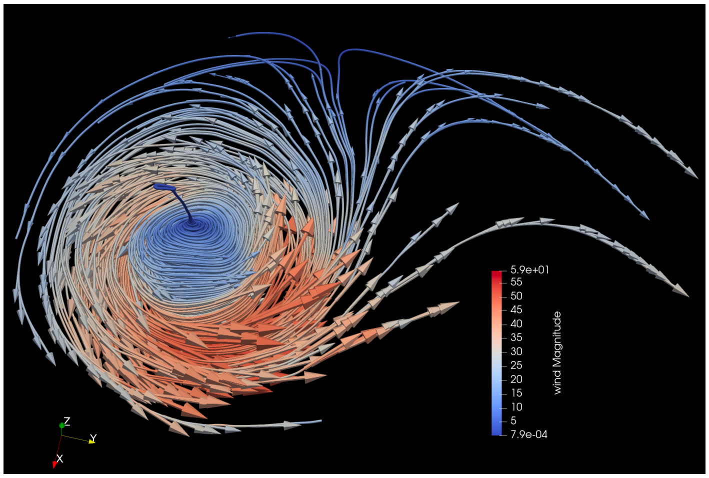

Fig 10. Arrow Glyph with seed type point cloud to visualize hurricane Katrina.

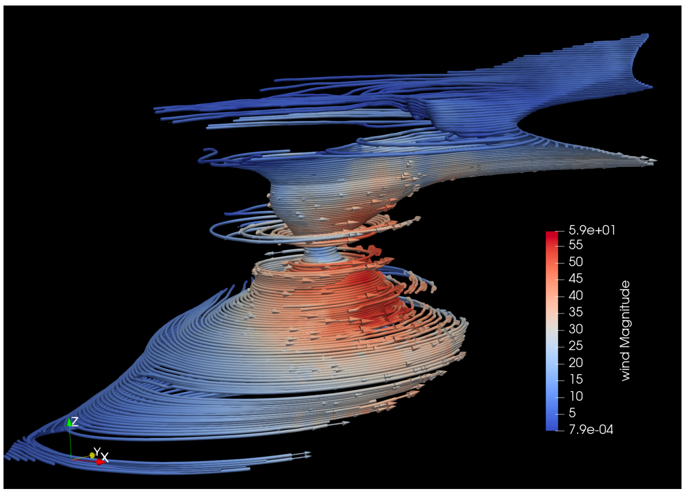

Fig 11. Arrow Glyph with seed type line to visualize hurricane Katrina.

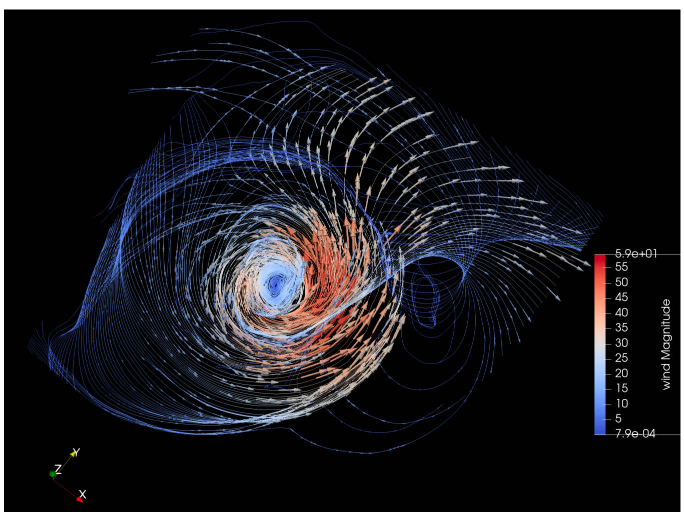

Fig 12. Arrow Glyph with seed type line without tube to visualize hurricane Katrina.

Part 3: Visualization of Air Flow around a moving car [25 pts]

1. I loaded the dataset in Paraview.

2. Applied the 1D transfer function to visualize the volume rendering of flow velocity magnitude across the moving car where Red represents relatively high magnitude and blue represents relatively low magnitude (Figure 13).

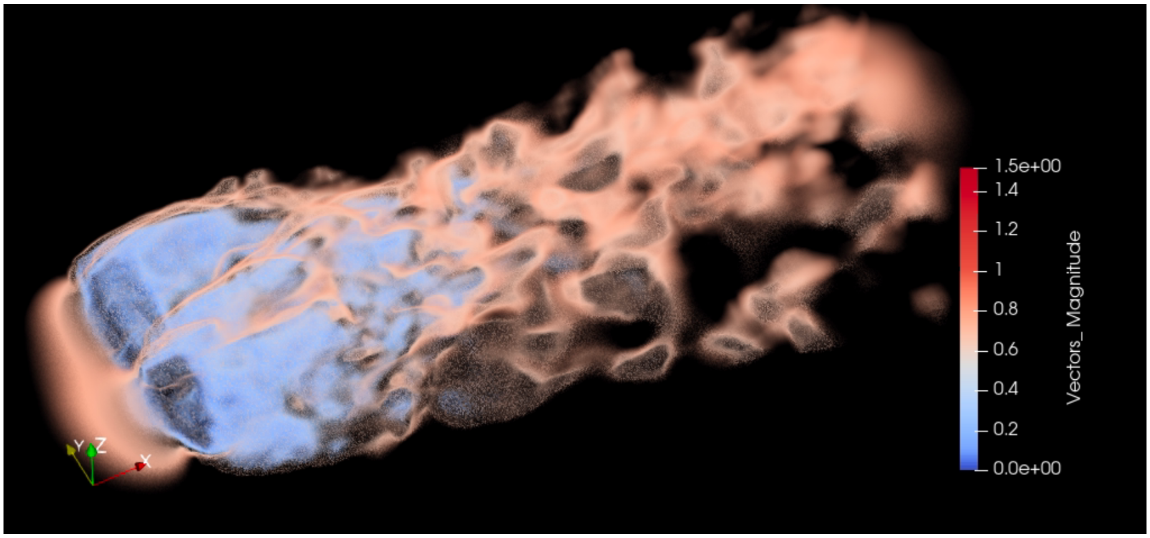

Fig 13. Volume rendering of moving car flow velocity magnitude with 1D transfer function.

3. I applied the stream tracer filter keeping the seed line orthogonal to the flow direction and kept it horizontal. Figure 14 represents the streamlines across the moving car.

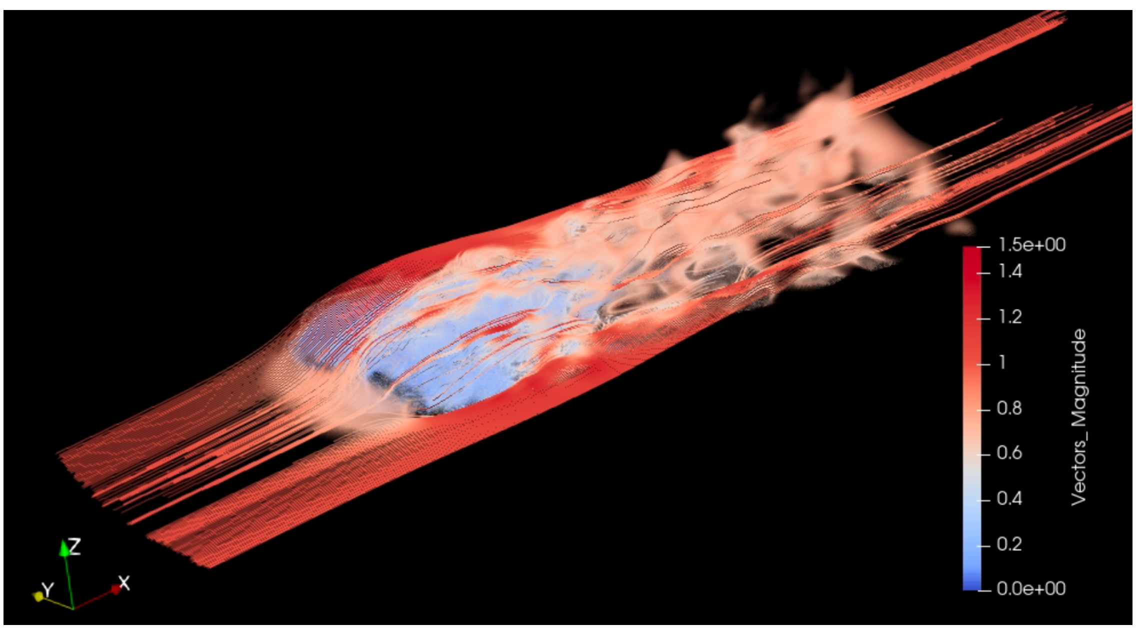

Figure 14 represents the streamlines across the moving car with seed type line and orthogonal to the flow direction

4. I applied the ribbon filter to the stream tracer to obtain better visualization. I adjusted the ribbon width and streamline resolution to obtain the below image.

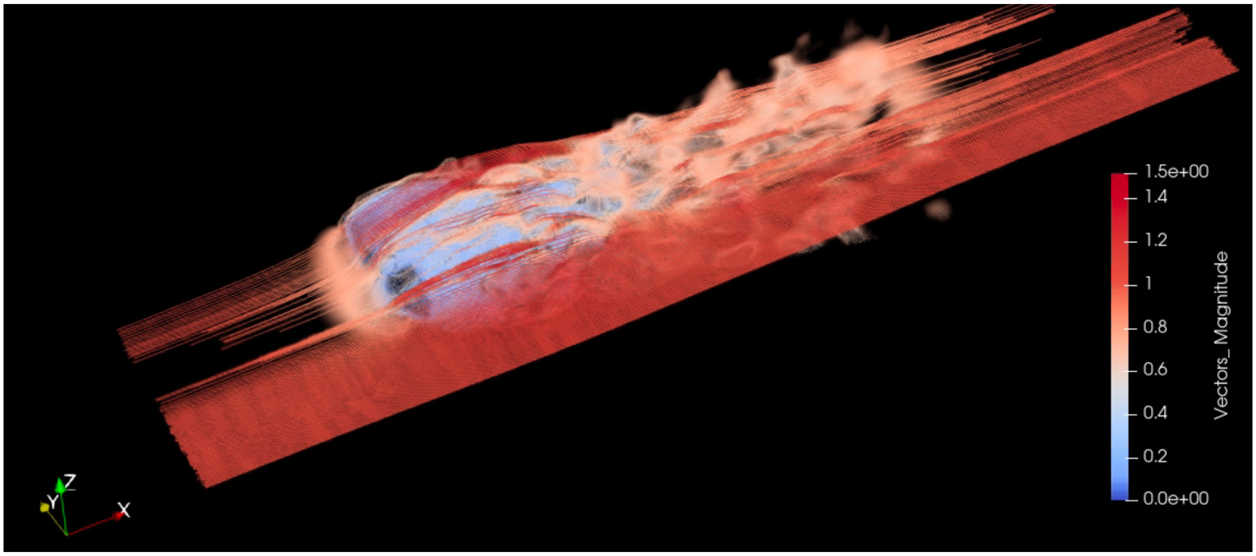

Figure 15 represents the streamlines across the moving car with seed type line and orthogonal to the flow direction with ribbon filter

5. We were asked to create the visualizations like image in question 4 for **two more** seed configurations.

First, I applied the seed line in the direction of the moving car and used the ribbon filter as shown in the figure 16. Furthermore, I applied the seed line orthogonal to the moving car direction in the Z axis as shown in figure 17.

From these images it can be inferred that with the streamline tracer we can capture the intricate flow streamlines across the moving car. The shape of the car is not uniform therefor the flow streamlines are quite complicated across the surface of the car. We can see the helical flow trajectory near the turbulent areas across the surface of the car.

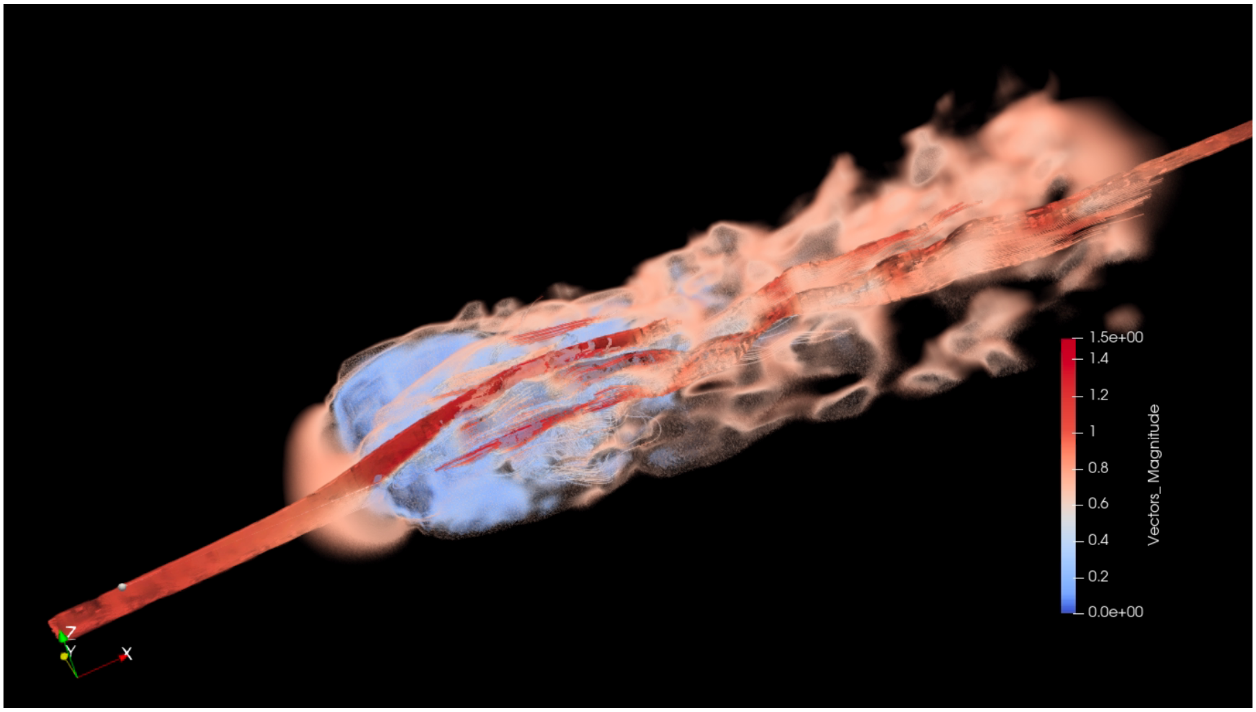

Figure 16 represents the streamlines across the moving car with seed type line across the flow direction with ribbon filter

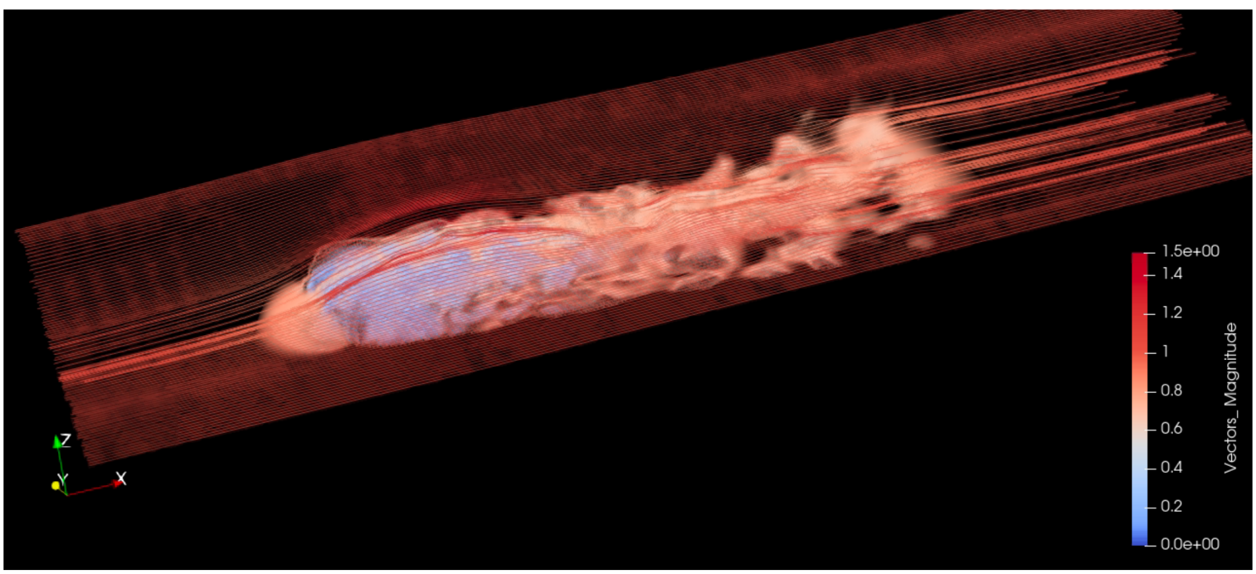

Figure 17 represents the streamlines across the moving car with seed type line orthogonal to the flow direction in the Z direction with ribbon filter

Part 4 Euler’s method to trace the streamline.

1. Generated 15 seed points using random sampling in the range [0,19] in x and y direction. Figure 18 shows the 15 random seep points colored in red.

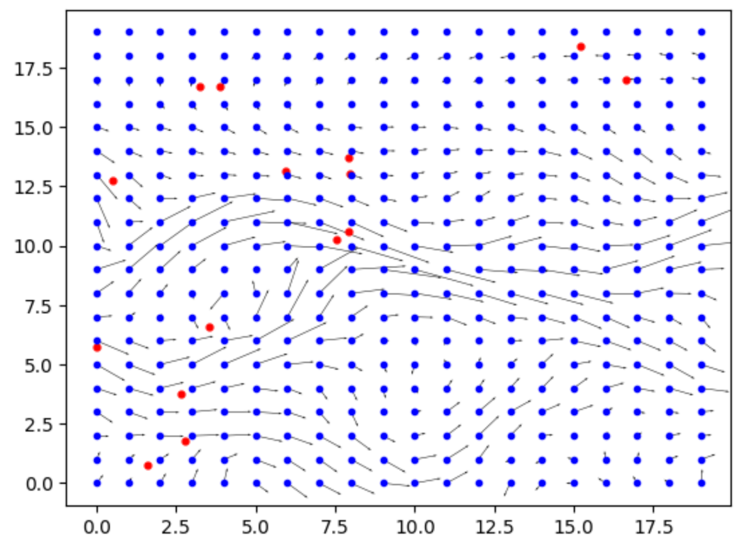

Figure 18 shows the 15 random seed points colored in red.

2. Traced the streamline from each seed point using the Euler’s method. First applied the Bilinear interpolation to obtain the velocity vector at each starting seed point and applied Euler’s method to trace the streamline with step size 0.3 and number of steps 8 (Figure 19)

3. Furthermore, the streamlines are generated at different step size and number of steps.
   Figure 20. Step size 0.15, steps 16
   Figure 21. Step size 0.075, steps 32
   Figure 22. Step size 0.0375, steps 64

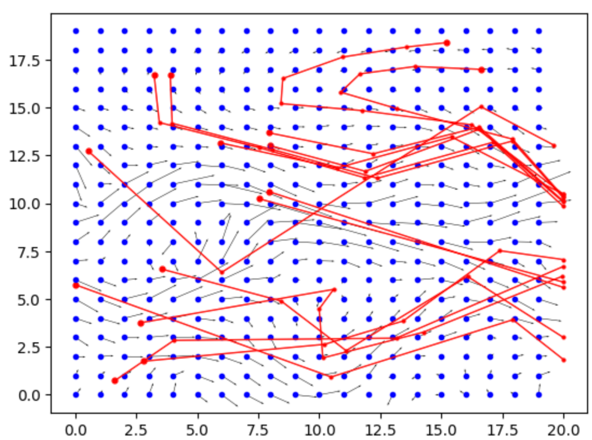

Fig 19. streamline with step size 0.3 and steps 8.

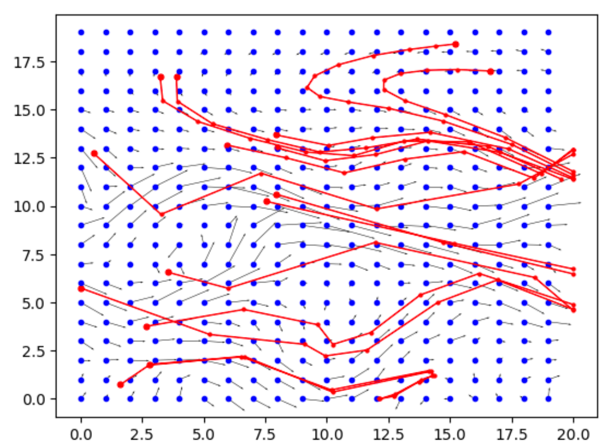

Fig 20 streamline with step size 0.15 and steps 16.

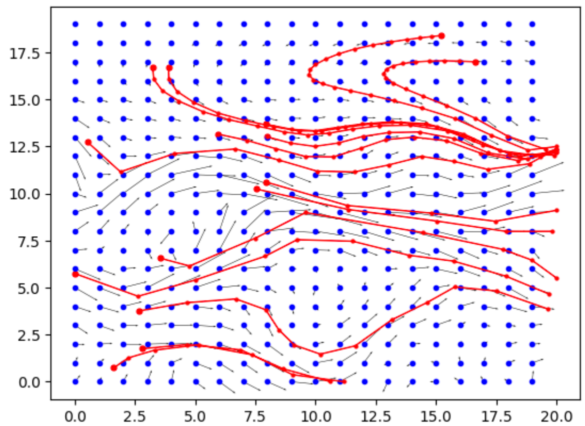

Fig 21. streamline with step size 0.075 and steps 32.

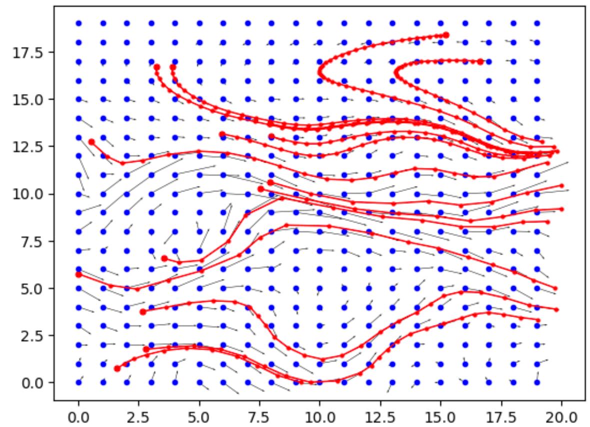

Fig 22. streamline with step size 0.0375and steps 64

From these figures, we can infer that at the higher time step, we miss some of the velocity vector information and the accuracy for obtaining the next positon is very poor. Fig 19. Shows more zig-zag streamlines. However, as we increase the time step the stream lines became more smooth as we incroporate more information obatined from the velocity vectors. The accuracy in obtaining the next position is high.

Part 4 Extra Credit: Runge-Kutta Method [10 pts]

1. Traced the streamline from each seed point using the **Runge-Kutta** method. First applied the Bilinear interpolation to obtain the velocity vector at each starting seed point and applied **Runge-Kutta** method to trace the streamline with step size 0.3 and number of steps 8 (Figure 23)

2. Furthermore, the streamlines are generated at different step size and number of steps using RK method.
   Figure 24. Step size 0.15, steps 16
   Figure 25. Step size 0.075, steps 32
   Figure 26. Step size 0.0375, steps 64

If we compare Euler and RK4 integration technique. In RK4, we consider velocity vectors at the aveage of the time steps hence, even with the lower time step we get better accuarcy and smoother streamline as compared to the Euler method.

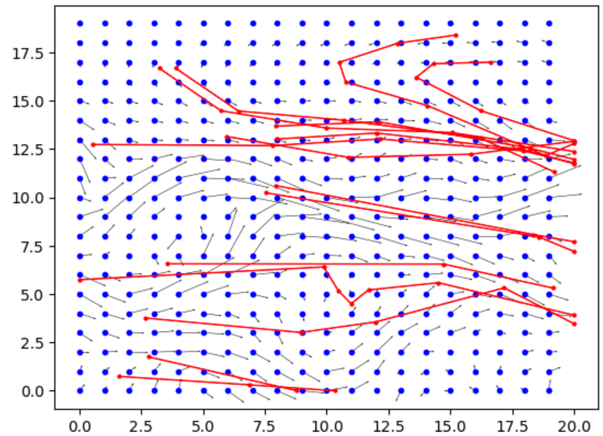

Fig 23. streamline with step size 0.3 and steps 8.

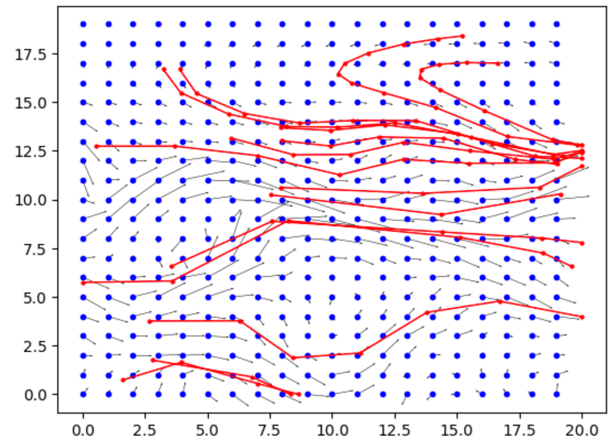

Fig 24 streamline with step size 0.15 and steps 16.

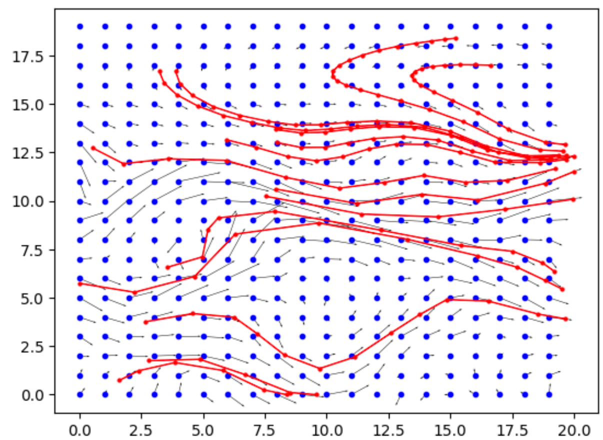

Fig 25. streamline with step size 0.075 and steps 32.

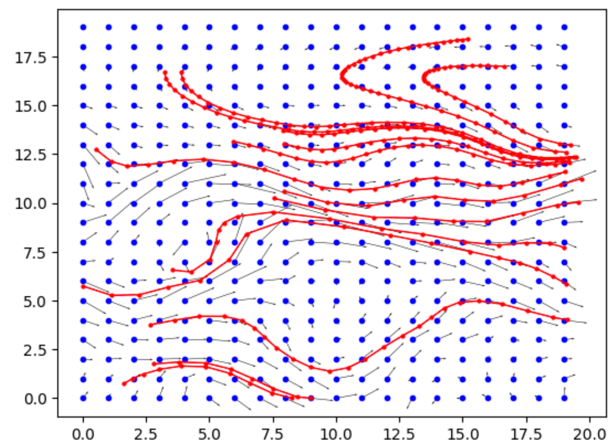

Fig 26. streamline with step size 0.0375and steps 64

Part 5: The reading questions

1.

Steady flows are time independent flows, flow does not change with time. Steady flows behaviors and features are well understood for example laminar flow.

Unsteady flows are time dedpendent flows, flow changes with time. Difficult to charactrize the unstead flows for example turbulent flow, combution flow.

Streamlines: The curve which is parallel / tangential to the vector field at each point for a fixed time.

Pathlines: The curve that follows the path of a particle over time through a vector field.

2. Briefly describe any three classifications of vector-field visualization techniques.

Three classification techniques for vector field visualization

a. Point-based direct visualization

This method is very straightforward and simple without any need of processing of data. For example, arrow plot where small arrow represents the flow direction and magnitude at discrete points. However, there are issues while representing complex data using point-based visualization because of clutter and occlusion.

b. Particle tracing in time dependent flow fields

It involves computing path lines, streamlines and streak lines which represent the trajectory of the particles within the flow used to understand the transport along the flow.

c. Dense representation in particle tracing

It uses texture-based technique for high spatial flow resolution for example Line Integral convolution produces images by convoluting a white noise texture with streamlines.

3. State any three features for feature-based vector field visualizations. Describe any two features in detail. Why is feature-based visualization important for vector field data?

Three fetaures for the feature based vector field visualization are Flow topoloy based on critical points, vortex detection techniques and geometry based global methods.

Flow topology based on critical points: Topology based visualization helps in understanfing the complex flow patterns using a reduced representation. It identifies the crtical points and provides essential information from simple diagrams

Vortex detection techniques: To understand the flow dynamics vortex based technique is very important which is applided directly on the vector data to identiyf the rotaitonal movements. This method identifies and visualize the vertices and provides information about complex flow.

Importance of feature based visualization:
Feature based visualization is essential as it highlights the flow’s critical features and avoids the redundant information. It provides a more abstract representation of the important features in a condensed form. Its captures the complex flow dyanmics focusing on phenomena like vortices, shock waves and flow topology. It focuses on key feature based visualization to help the users to understand the complex flow dynamics and more interpretable.

Conclusion:
This assignment helped me understanding the visualization of the vector field using stream tracer, tube and Glyphs.

- In stream tracer we can change the seed type to point to capture the details of the specific areas. We can set the line seed to capture the detail streamlines of the entire plane.
- The visualization gets enhanced by using the tubes.
- Glyphs arrows and cones with proper color mapping are used to visualize the vector field magnitude and direction.
- Stream tracer with ribbon filter helps in understanding the complicated flow profile.
- While tracing the streamline I applied Euler and RK4 integration technique. With small step size the streamlines are not accurate however as we increase the step size we get more accurate and smooth streamlines.

References

1. en.wikipedia.org/wiki/Euler_method
2. wikipedia.org/wiki/Bilinear_interpolation
3. wikipedia.org/wiki/Runge–Kutta_methods