Feature Identification, Matching and Visualization of the evolution of instantaneous speed for 3D vortex street data

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1 Problem Statement

Performing feature extraction and overview visualisation is an important topic in scientific visualisation. It allows us to detect and track evolutions of regions of interest over time-varying data, which is central to many scientific domains. Topological data analysis has been used in last decades as a robust and reliable setting for hierarchically defining features in time-varying data. Many state-of-art techniques implementing this suffers with high computation cost when applied on large-scale dataset which are not uncommon in today's world. There is a need of efficient feature detection and tracking technique which is reasonable in terms on computational cost even when applied to large data.

In this project, given a time-varying dataset, optimal matching of topological structures (namely persistence diagrams) is done between two successive timesteps using modification to seminal assignment algorithm proposed by Kuhn and Munkres [3]. This matching is based on lifted Wasserstein's distance metric.

References

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[5] M. Soler, M. Plainchault, B. Conche, and J. Tierny, "Lifted wasserstein matcher for fast and robust topology tracking," *CoRR*, vol. abs/1808.05870, 2018. [Online]. Available: http://arxiv.org/abs/1808.05870

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2 Work Completed

- Extracted Persistence diagrams for each time step using TTK Paraview[7] [1].
- Implemented modified Kuhn Munkres algorithm (also referred as Hungarian Algorithm) [5] for optimal matching.
- Constructed cost matrix for the assignment problem for each pair of consecutive time step using lifted Wasserstein distance metric.
- Computed matching matrix between two consecutive time steps using modified Hungarian algorithm and cost matrix.
- Correlated persistence pairs between persistence diagrams of two consecutive time steps.
- Correlated matching coordinates in the scalar field data using the persistence diagram and matching matrix using pyvista [6] .
- Generated visualisation using the matched coordinates over all time steps using pyvista [6] and paraview [1].
- Generated visualisation using the matched coordinates over all time steps using pyvista [6] and paraview [1].
- Observed five max distance covering critical points and generate a trace out of it using pyvista [6] and paraview [1].

3 Results and Evaluation

This section shows the results generated after the visualization and matching of the instantaneous speed data.

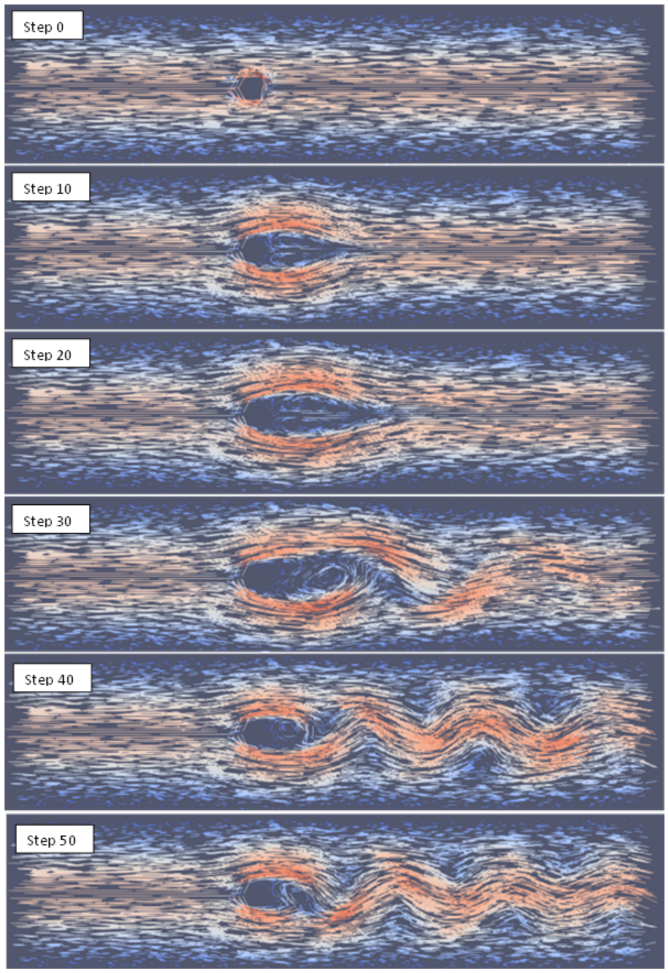

Fig. 1: Overview Of Vector Flow

Figure 1 shows the evolution of the actual Vortex Street vector data across different time steps.

The persistence pairs were generated for each time step and after application of modified Hungarian [3] algorithm for matching pairs. Matched persistence pairs are shown in Figure 2 for two consecutive time steps 1-2.

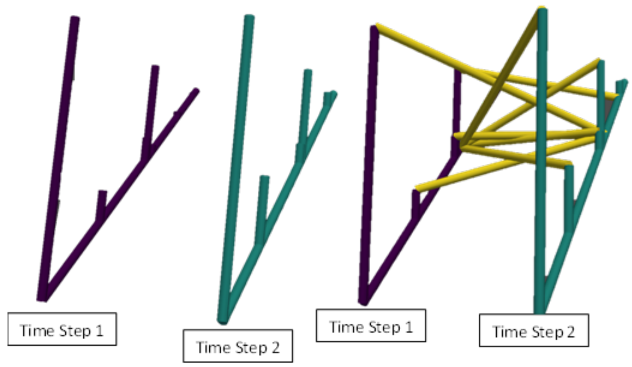

Fig. 2: Matching of persistence Pairs

The matching matrix is generated for each consecutive time step pair. Using this matching matrix, the critical points across the time steps were correlated. The result of which are shown in Figure 3 for four consecutive time steps.

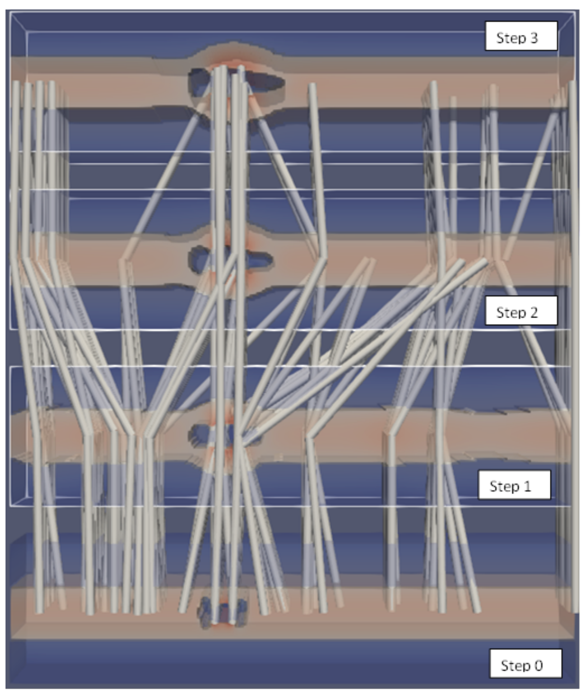

Fig. 3: Matching of points across different time steps

Once correlated the critical points are overlaid on the the data to visualize the change in positions of the critical points across all the time steps. The overview of which can be seen in Figure 4. The matching critical points are given same label to identify them across time steps.

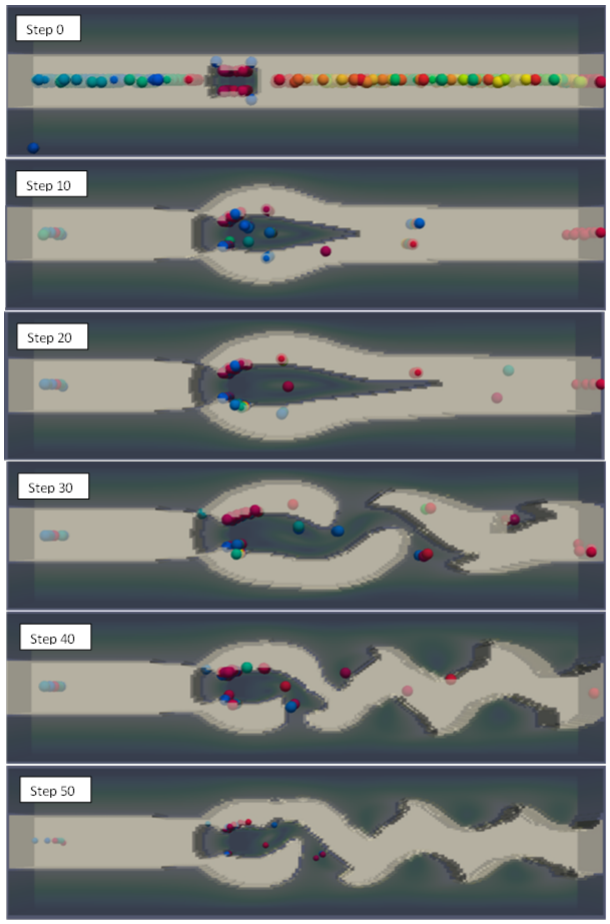

Fig. 4: Overview Of Matched Points

Using the generated correlation, 5 max distance travelled critical point were observed. There trace was generated which is shown in Figure 5.
The same has been tabulated in Table 1.

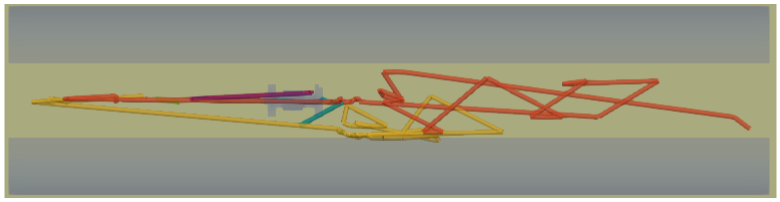

Fig. 5: Tracing 5 most travelled points

Coordinates	Distance Travelled
(-7.499, -0.125, 5.375)	26.536
(-3.998, 0.0, 5.625)	23.041
(-0.498, -0.625, 4.75)	20.353
(-3.832, -0.125, 2.375)	20.036
(-2.331, 0.0, 0.125)	18.504

Tab. 1: Five most travelled Critical Points (Coords in step 0)

4 Discussion

The most prominent features of the project that were also difficult to implement includes:

- Converting dataset from AmiraMesh (.am) format to Paraview readable (.vtk) format for loading dataset into Paraview.
- Implementing Modified Hungarian algorithm as given in [5]
- Generating correlation matrix from individual matching matrix. For which each from time step zero each critical point has to be traced across time steps using individual matching matrices.
- Generating solidified connections for connecting pair of points. For this cylinders are used whose height depends upon the magnitude of the direction vector.

5 Individual Contributions

1. **Lakhan Malviya** :

   - Parsing dataset to convert from 3-component vector field to scalar field by taking L_2 norm of each element in the field.
   - Converting dataset from .am file to .vtk file type to load into Paraview
   - Extracting persistence diagram for each timestep using Paraview TTK and loading them into csv file.

2. **Rohit Prasad** :

   - Implementation of Modified Hungarian algorithm [5] for the matching problem.
   - Construction of cost matrix from persistence diagram created in Paraview for each pair of consecutive timestep. Cost for each element in matrix is assigned based on lifted Wasserstein metric.

3. **Ichchhit Baranwal** :

   - Generation of Correlation matrix from matching matrix.
   - Generation of Visuals.
   - Observed 5 max distance travelled points and generated trace for it.