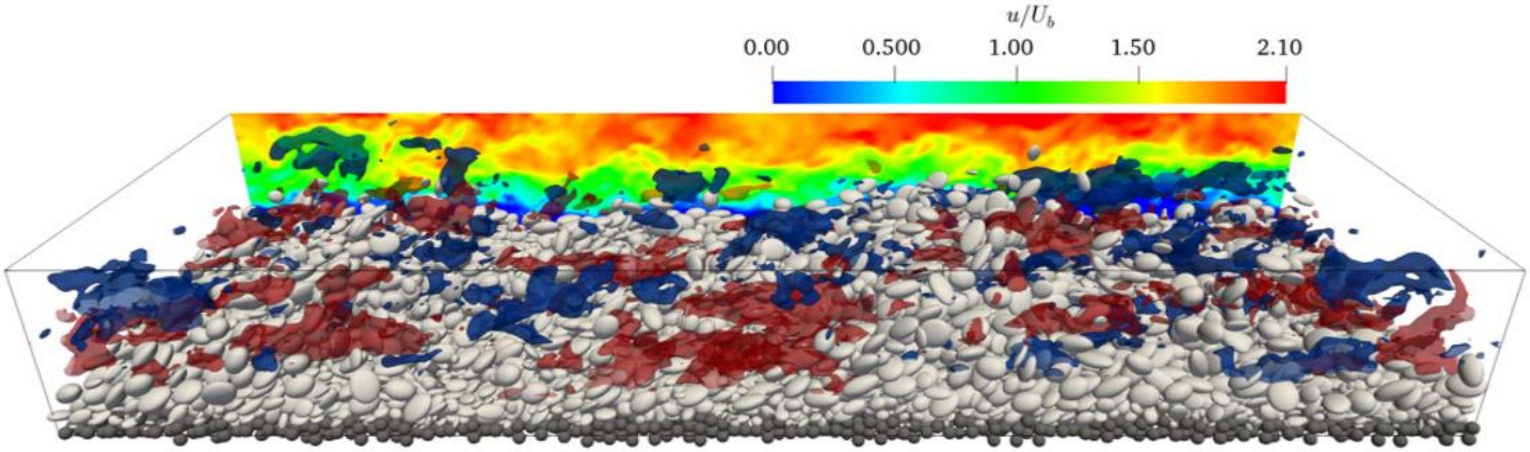
17.12.2018

Visualization of trajectories of ellipsoid-shaped particles

Diploma Thesis

Franziska Krüger

Introduction



Visualization of simulation data by group of Prof. Fröhlich

- Analysis of movement patterns of particle data
- Trajectory showing particle position at every time step at once

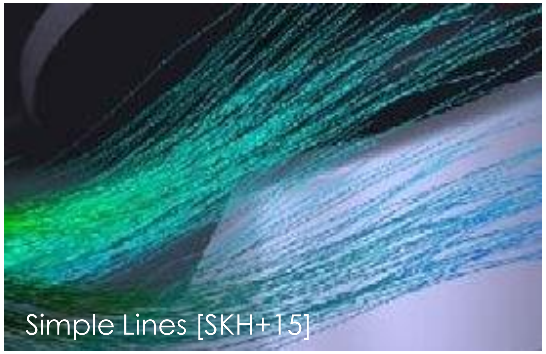
Content

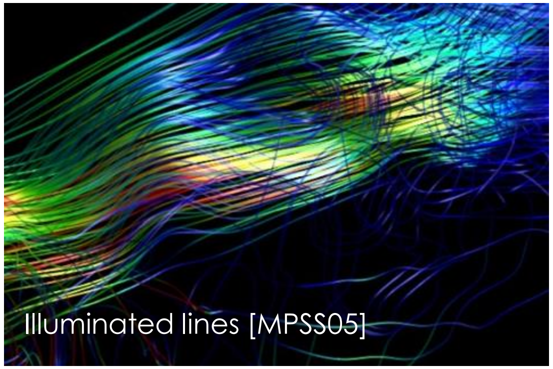
1. Introduction
2. Related Work
3. Conception
4. Implementation
5. Evaluation
6. Conclusion

Trajectory Visualization Techniques

Line

- Lighting infinitesimally thin cylindrical tubes [MPSS05]
- Depth-dependent halos [EBRI09]
- Ambient occlusion [EHS13]

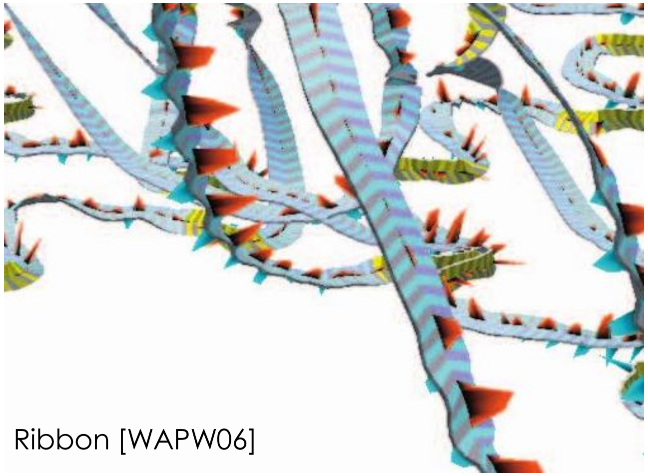




Trajectory Visualization Techniques

Ribbon

- Stream ribbons [USM96]
- Combination with glyphs [WAPW06]

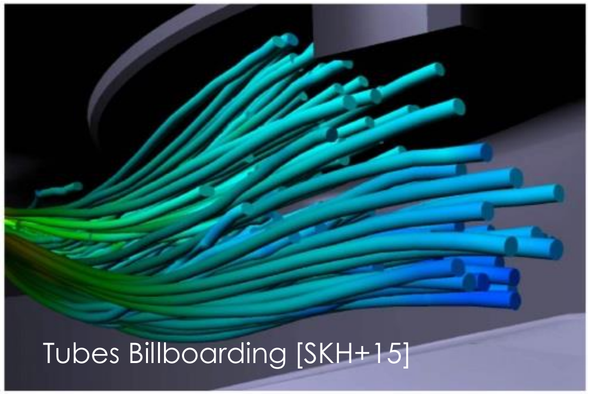


Ribbon [WAPW06]

Trajectory Visualization Techniques

Tube

- Generalized Cylinders [AB76] [SVL91] [GM03]
- Stylized line primitives with color, width and texture for attribute encoding [SGS05]
- Hyperstreamlines [DH93]
- Blending of stream balls [BHR+94]
- Billboarding [SKH+05]


Tubes Billboarding [SKH+15]


Textured Tubes [SGS05]

Visualization Goal

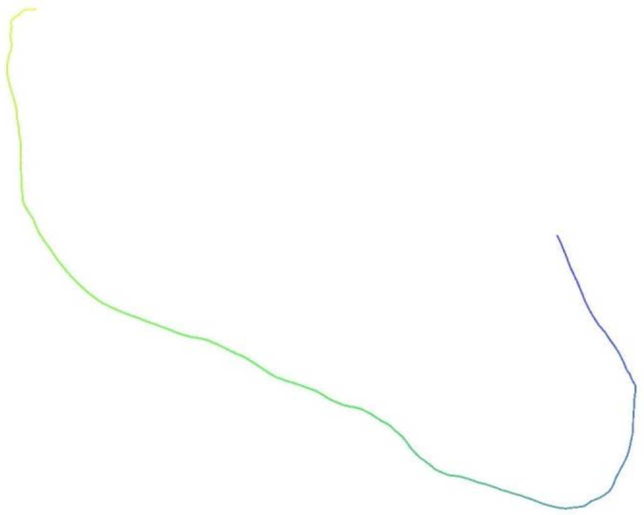
- Conveying particle properties:
  - Position
  - Time
  - Orientation (pose)
  - Linear velocity
  - Angular velocity

Trajectory with particle at every 40th time step

- Requirements of group of Prof. Fröhlich:
  - Filter based on traveled distance in specific direction
  - Overview of data set like random walks

Line

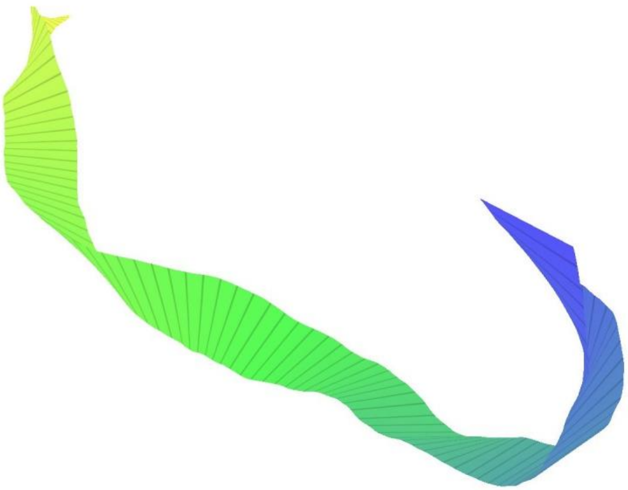
- Color
  - Time steps
  - Transition from yellow (start) to blue (end)



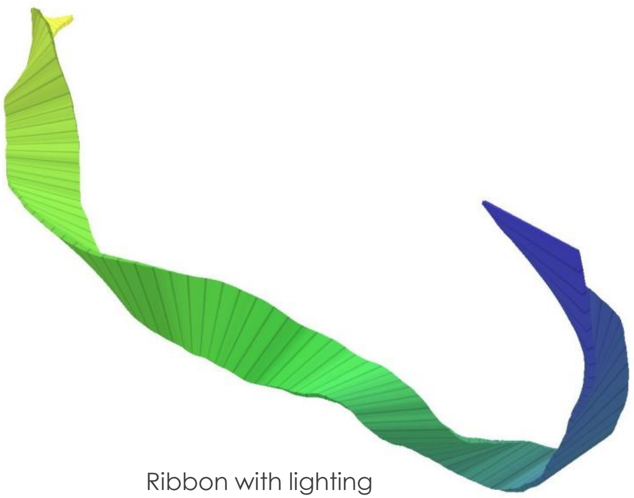
Line

Ribbon

- Ribbon width:
  - based on largest principal axis of ellipsoid
  - Orientation indication
- Color:
  - time steps as for lines
- Darker ticks at every 10. time step
  - Orientation indication
  - Velocity indication
- 3D Ribbon with lighting



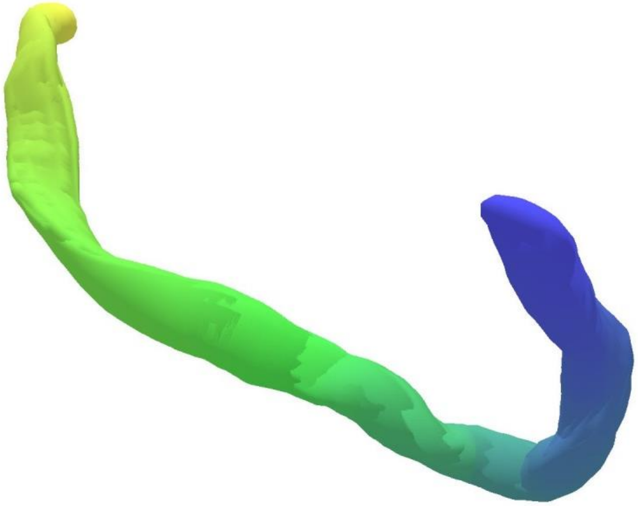
Ribbon



Ribbon with lighting

Tube

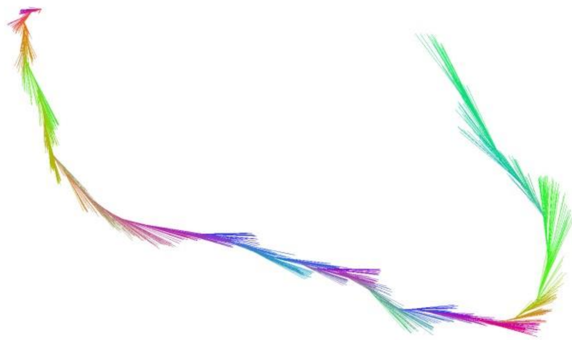
- Displaying all ellipsoid positions of trajectory at once
- Color:
  - Time steps
- Glyphs need to be moved to tube surface



Glyphs for velocity

Linear velocity

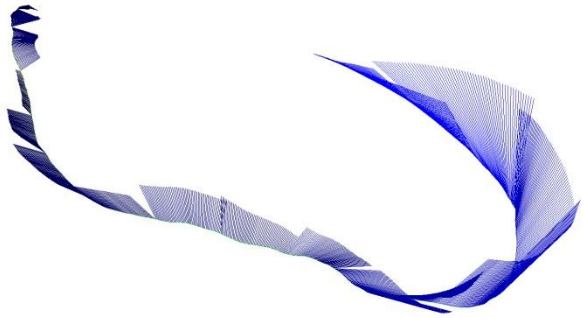
- Line in movement direction
- Color: movement direction (velocity vector as RGB-vector) or value of velocity
- Length: value of velocity



Linear velocity with movement direction as color

Angular velocity

- Line as rotation axis
- Color: direction of axis or value of velocity
- Length: value of velocity

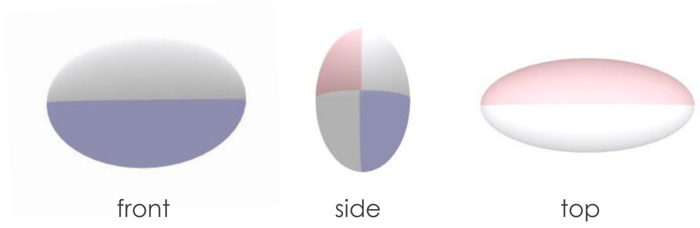


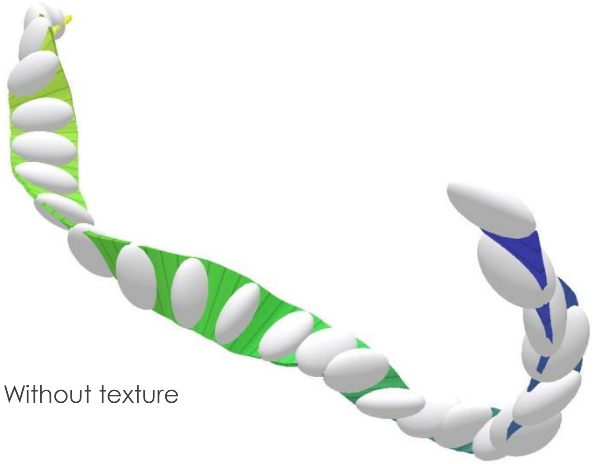
Angular velocity with value of velocity as color

- Allows for relative comparison

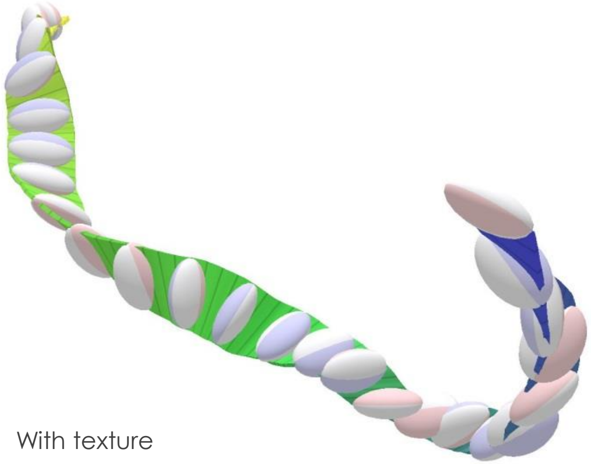
Ellipsoids at Time Steps

- Displaying all ellipsoid at certain time steps
- Adding texture to ellipsoids for determining rotation of particle





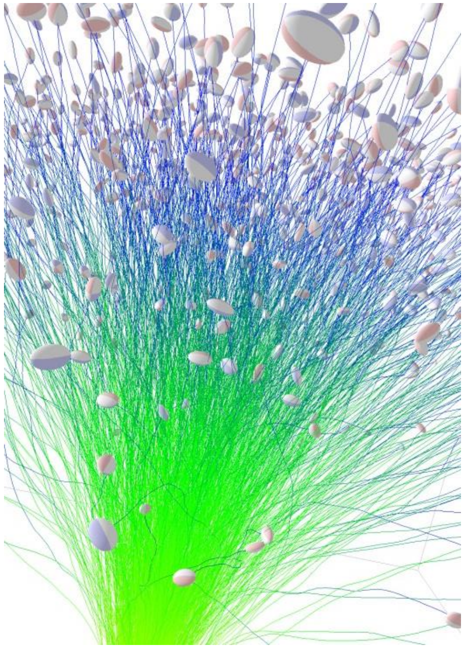
Without texture



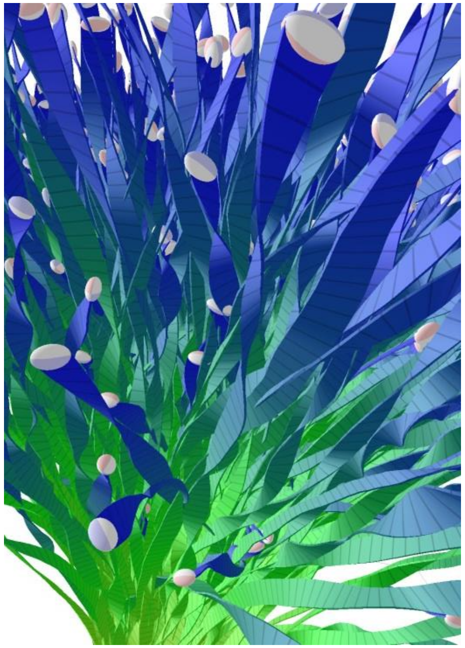
With texture

Comparison

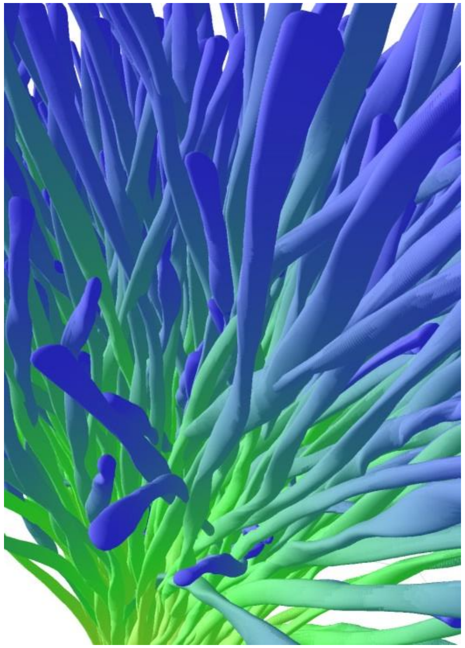
- Lines have the least available attributes for visualization
- Ribbons in combination with ellipsoids at certain time steps best choice



lines



ribbons



tubes

Filter

- Temporal and spatial filter to view only subset of data set

Temporal Filter

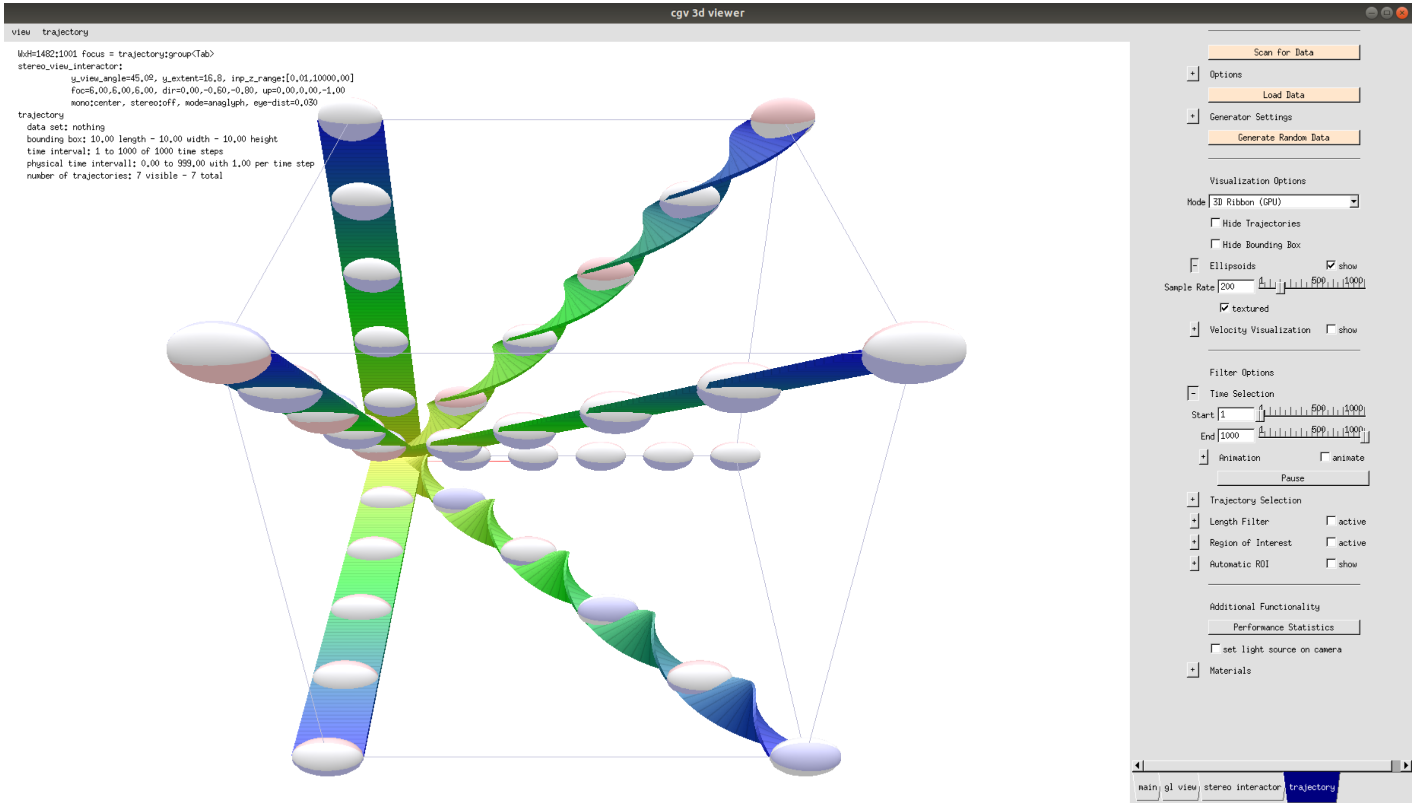
- Time interval selection

Spatial Filter

- Length filter
- Region of interest

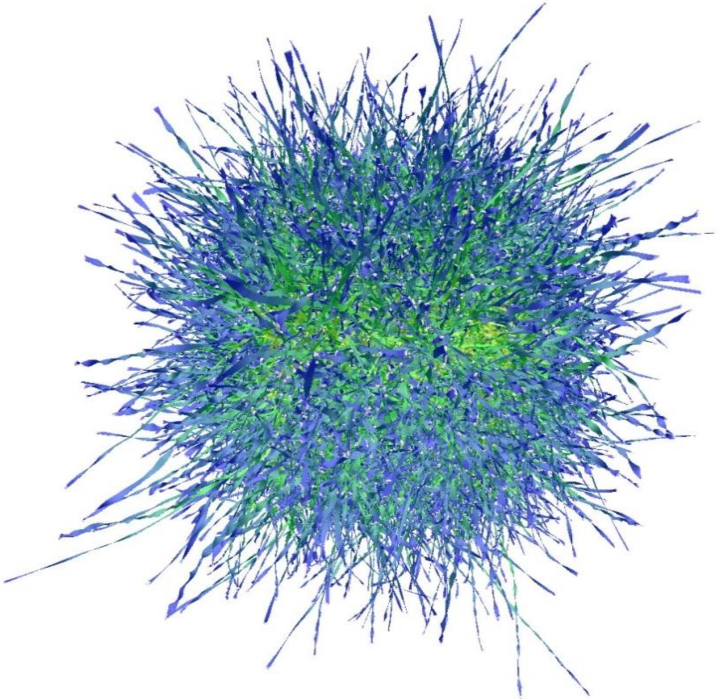
Region of interest

Application

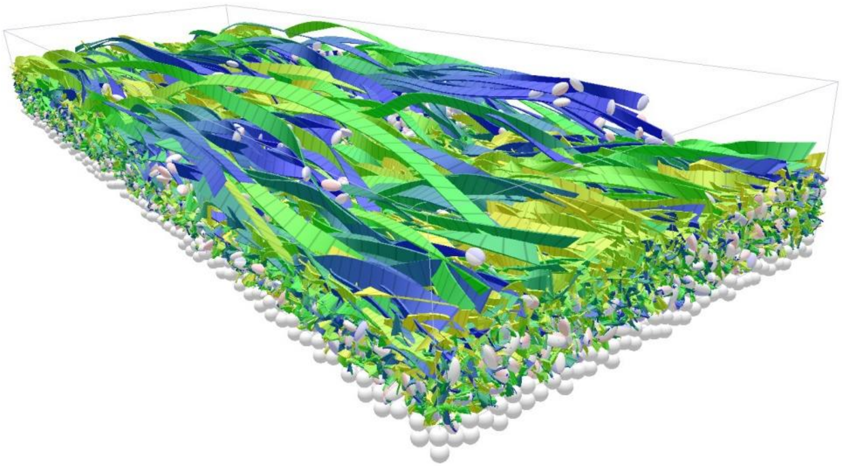


- cgv-framework with OpenGL Core Profile

Input Data



Random generated data

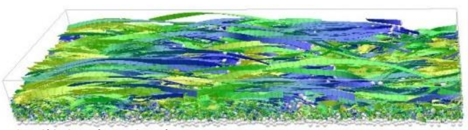


Simulation Data

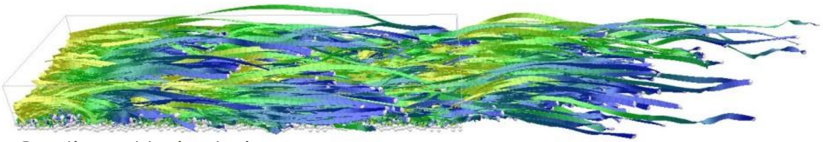
- Trajectory data containing particles axes, positions, orientations and time

Post-Processing

- Computation of necessary variables like angular and linear velocity or normals
- Interpolation of equidistant points (in time)
- Splitting or continuing trajectories



Split trajectories



Continued trajectories

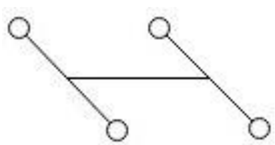
Renderer

- Indexed rendering for lines and ribbons
- Instanced rendering for tubes and ellipsoids at certain time steps

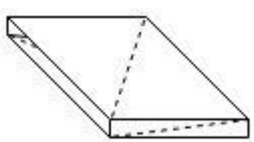
GPU-Implementation for 3D ribbon

- Using geometry shader with lines as input and triangle strips as output

Input line



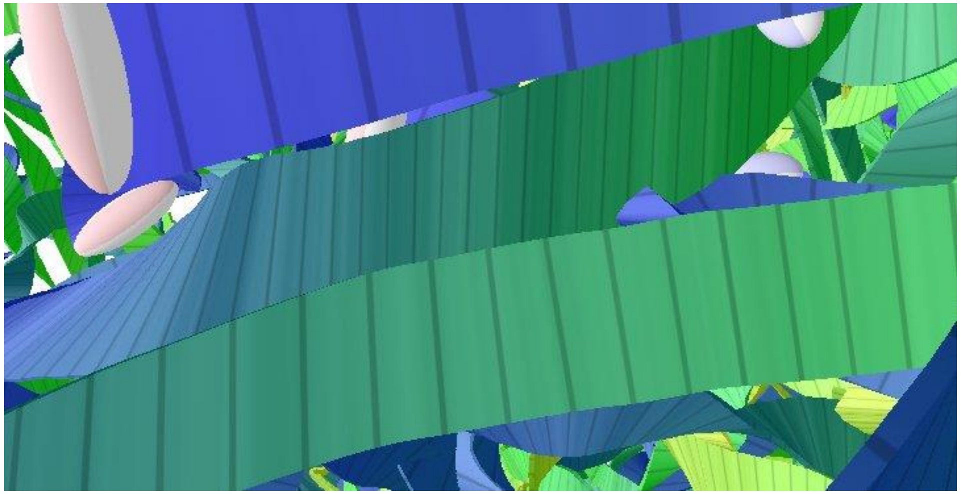
End points of each axis



Ribbon surface

Dark Ticks on Ribbon

- Procedurally generated using shader
  - Time information and step count for vertex shader
  - Sigmoid-shaped thresholds in fragment shader



Evaluation

1. Performance Measurement
   - GPU computation time and memory usage

2. Parameter Study of Ribbon Visualization
   - Height
   - Material parameter

3. Application on Simulation Data Set
   - Overview of data set

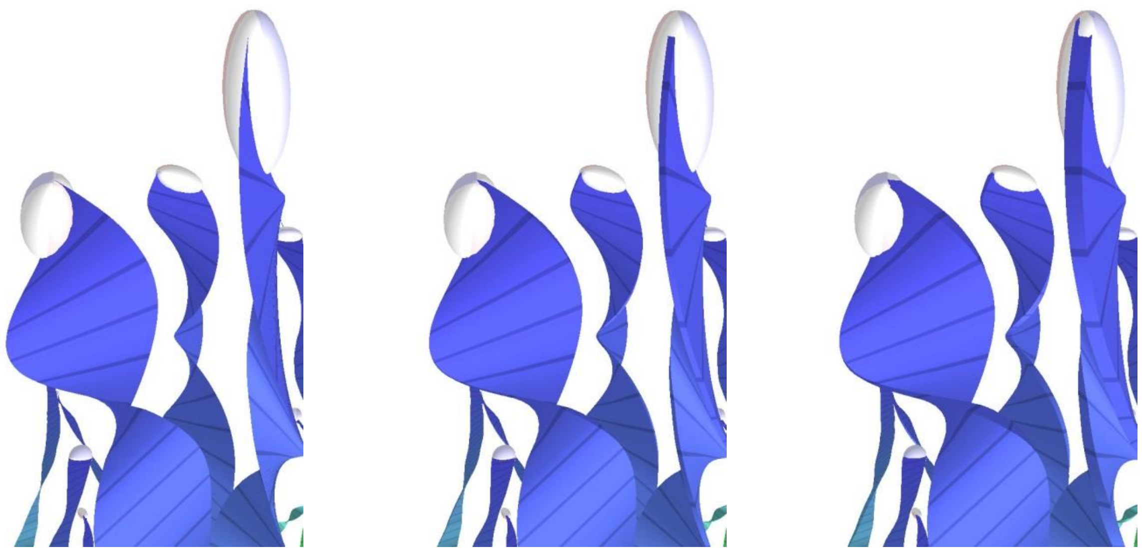
Performance Measurement

Visualization	Primitives	RAM	GPU Memory	GPU-time
Line	14 980 001 lines	1.8 GB	0.5 GB	1.15 ms
Ribbon 2D	29 960 000 triangles	2.5 GB	1.0 GB	1.41 ms
Ribbon 3D	119 840 000 triangles	9.6 GB	5.0 GB	32.95 ms
Ribbon 3D GPU	119 919 987 triangles	2.4 GB	1.2 GB	7.87 ms
Tube	2 308 460 003 triangles	2.5 GB	0.7 GB	54.50 ms
Velocity every Step	14 990 002 lines	2.2 GB	0.4 GB	1.89 ms
Ellipsoids at End	5 980 003 triangle	1.1 GB	0.0 GB	0.92 ms

- Evaluation results of a random generated data set with 10,000 trajectories and 1,500 time steps

Parameter Study for Ribbon Visualization

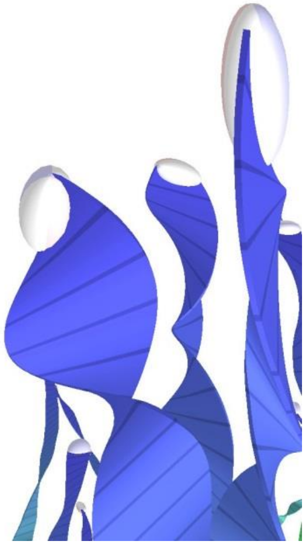
- Different heights:



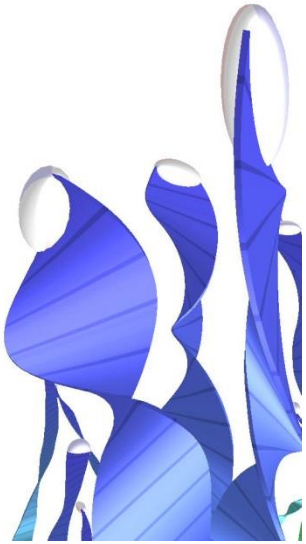
Height 0 Height 0.1 Height 0.25

Parameter Study for Ribbon Visualization

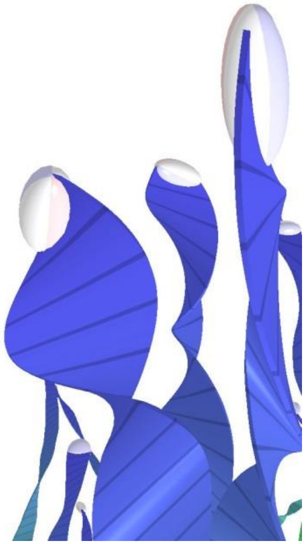
- Different material: specular parameter



No specularity



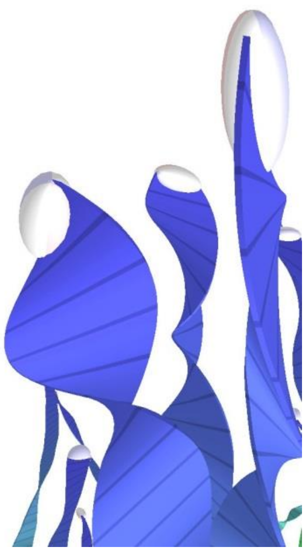
White with shininess 2



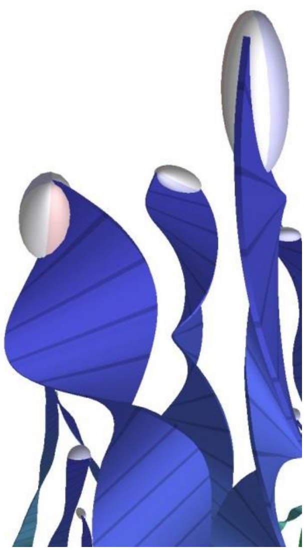
White with shininess 64

Parameter Study for Ribbon Visualization

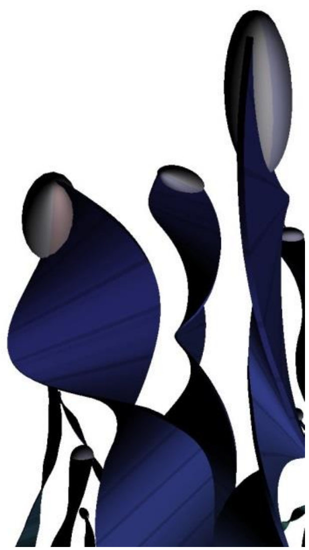
- Different material: ambient parameter



white



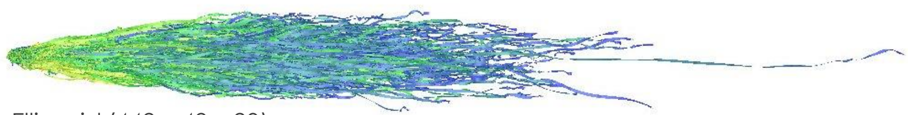
gray



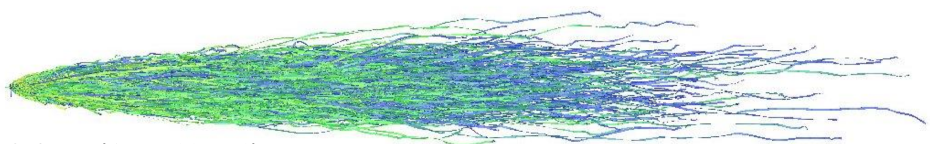
black

Application on Simulation Data Set

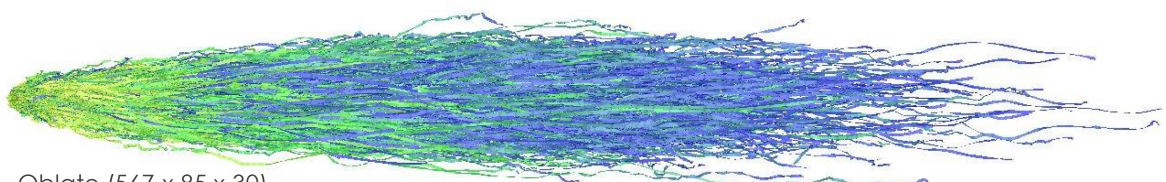
- Overview of all trajectories of each data set



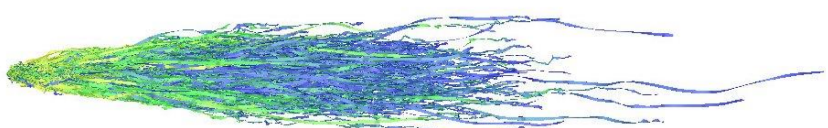
Ellipsoid (442 x 49 x 20)



Sphere (451 x 66 x 16)



Oblate (567 x 85 x 30)

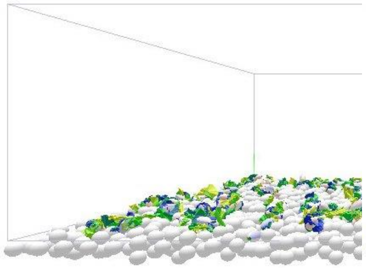


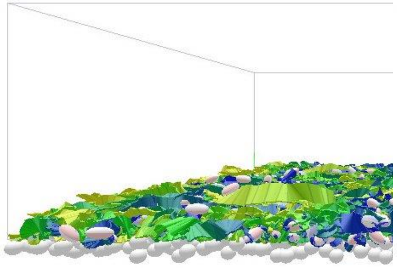
Prolate (401 x 59 x 26)

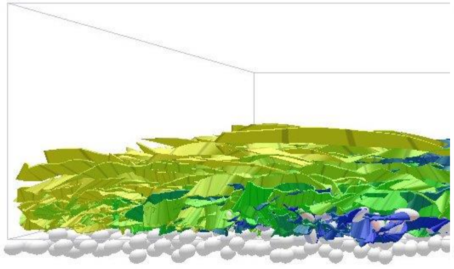
Application on Simulation Data Set

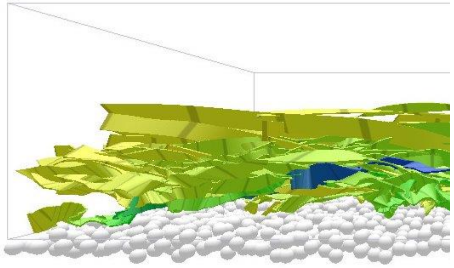
- Number of trajectories for each length category

Data Set	very short	short	medium	long	total
Ellipsoid	649	5,375	5,607	3,089	14,720
Sphere	10,245	1,700	987	1,788	14,720
Oblate	190	2,062	4,705	7,763	14,720
Prolate	348	4,359	6,965	3,048	14,720


Very short


short

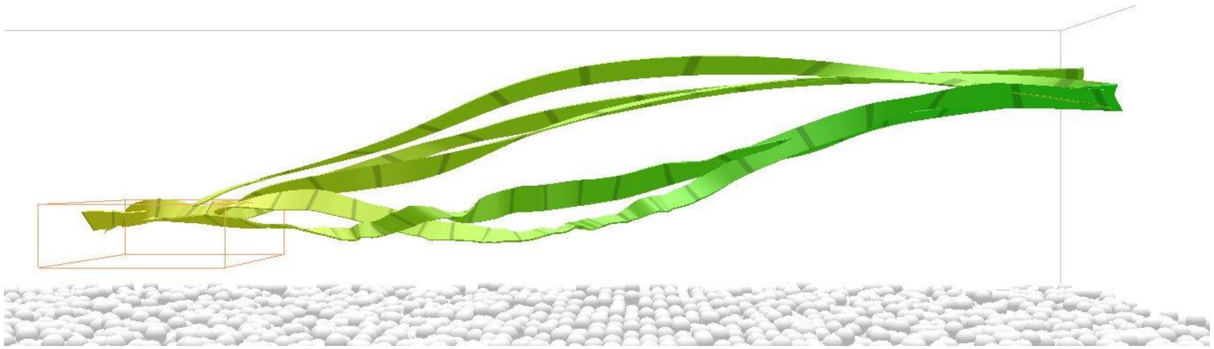

medium


long

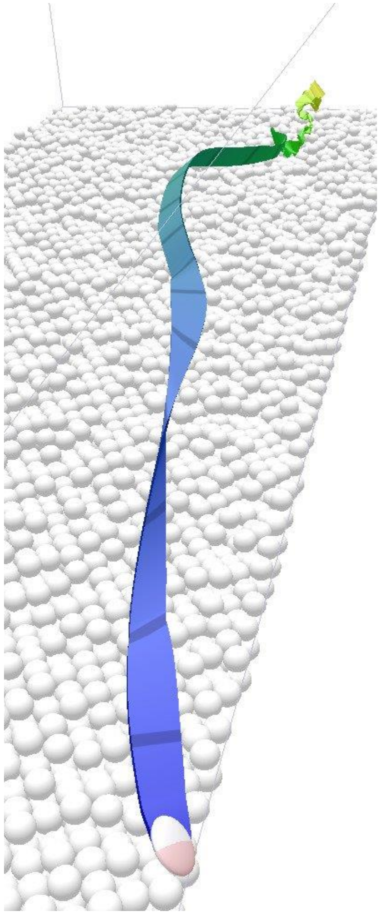
Prolate data set

Application on Simulation Data Set

- Some more results:
  - Single trajectory
  - Region of interest filtering long trajectories starting at same time



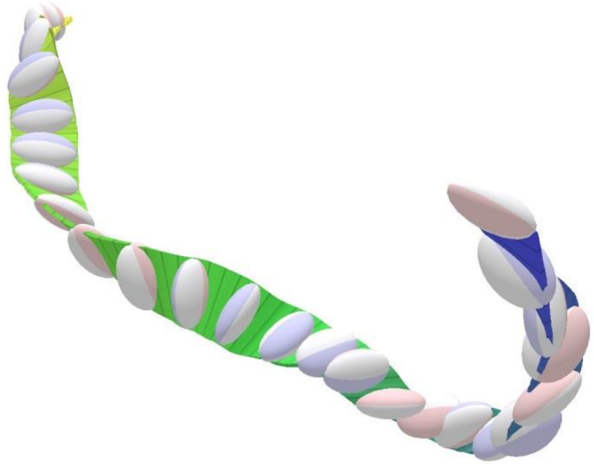
Region of interest



Single trajectory

Conclusion

- Ribbon visualization in combination with ellipsoids at time steps conveys most important particle properties
- Interactive data exploration



Ribbon Visualization with Ellipsoids at Time Steps

Future Work

- Line for degenerated ribbon
- Global lighting
- Focus-in-Context filter

Literature

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