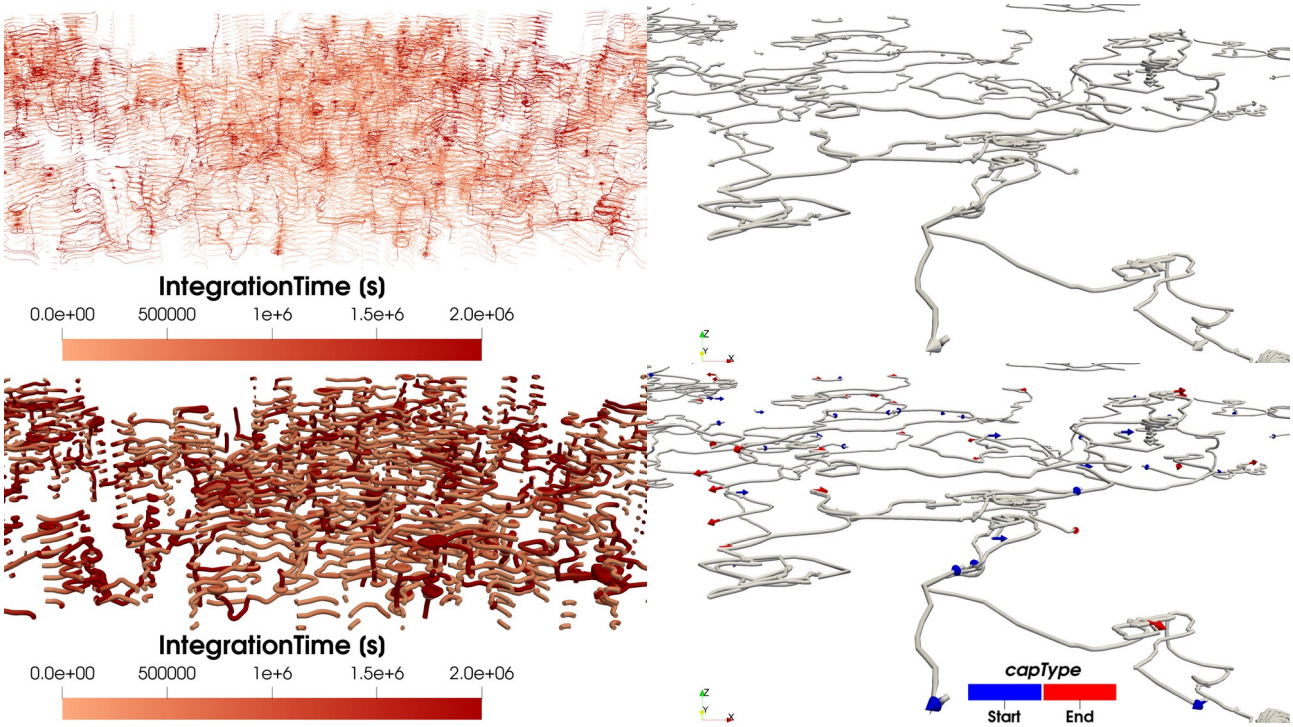
Exploring the Visual Design Space of 3D Lagrangian Flow Visualizations



In *computational fluid dynamics (CFD)* and oceanography, the tracing of particles in hydrodynamic fluid velocity fields is used to study the particles transport and their behaviour in Newtonian fluids. Such fluid dynamics study is called *Lagrangian simulation*, as the particles trajectory form through Lagrangian integration of their positions over time. The field of directional, hydrodynamic velocity tensors is the underpinning *Eulerian model*.

In order to extract higher-level insight from the physical simulations, we need to visualize the fluid fields and their particles within the same context. Creating such an effective *exploratory visualisation* is a *visual design challenge*, because the various ways of *mapping* the data to the *marks* and *channels* are not equally effective. Certain designs are more comprehensible and clean, while others suffer from visualisation artefacts, such as clutter, occlusions, *hallucinators* and *jumblers*.

The goal of this project is to qualify and quantify the effectiveness of various, competing visual designs of ***3D Lagrangian*** fluid-particle visualisation. The objectives here are to (a) fully explore the design space visualisation design space; (b) assess and highlight visualisation artefacts for each design; (c) provide an accessible, easy-to-use toolbox to generate competing visual designs for a given set of data on-the-fly. An inspirational starting point for this work is provided by Kehl et al. [1].

The project process is envisaged as such:

- Survey pre-selected literature: identify the design space of 3D Lagrangian fluid particle traces
- Survey and select visual design evaluation approaches or their taxonomies
- Design an experiment plan for the evaluation of the design space, according to the selected evaluation approach
- Design and develop a 3D graphics visualisation platform with a user interface to generate the target fluid flow visualisations interactively, including multi-perspective visual animation
- Replicate identified mapping techniques (*marks* & *channels*) for 3D Lagrangian fluid particles
- Experiment with the implemented visualisation designs according to the experiment plan
- Conclude on the adequacy, the benefits, the drawbacks and the visual artefacts of the selected design techniques – score the techniques, if the evaluation approach allows for it

[1] Kehl, C., Lobelle, D.M.A & van Sebille, E. (2022) Perceptual multivariate visualisation of volumetric Lagrangian fluid-flow processes. *Front. Environ. Sci.* 10:941910. doi: 10.3389/fenvs.2022.941910