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Variational 3D-PIV using Sparse Descriptors

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Abstract

In [1] we proposed a variational approach for 3D-PIV for incompressible fluids. We formalize, propose and evaluate different variants for both the data term and the regularizer. Best results were achieved with sum of squared differences (SSD) as data term and a novel regularization based on the Stationary Stokes Equations. This strictly enforces a divergence-free flow and additionally penalizes the squared gradient of the flow. Velocity estimation is performed on a regular grid, which can be of lower resolution than the inputting MART-reconstructed particle intensity volume. By using such a semi-dense formulation, we can reduce computation time and memory footprint without significant loss in accuracy (e.g. up to 4x lower resolution in each dimension, respectively 64x fewer variables). However, the discretization of the data term is still based on the high-resolution intensity voxel grid, whose size is chosen based on the image resolution. For bigger volumes, this leads to a large memory footprint, while the actual data, the particles, is sparse (i.e. for 0.1ppp and 350 depth slices we get approx. 0.0003 particles per voxel).

To overcome the coupling of the sparse particle data to the discretization of the volume, we propose a particle based data structure. In particular, we only need to store the particle location and intensity information but still can evaluate the data term at any position in the volume. Initial 3D particle reconstruction can be performed by MART and subsequent sub-voxel accurate peak detection or by direct particle based techniques like IPR. In practice, we chose the same regular grid to evaluate our novel data term based on the 3D sparse descriptor as for the flow estimation. The descriptor structure is defined by the descriptor radius and grid point layout, here different layouts are possible. We propose a layer based structure, with grid points arranged on a sphere on each layer. For uniform distribution of grid points on a sphere, one can use an icosahedron structure or subdivisions of it. A particle within the radius of the descriptor is then splatted to its k nearest grid points (with a distance-based weight). An example of such a descriptor is shown in 2D in Fig.1. We further show visual results of a reconstructed flow field compared to the ground truth flow from DNS simulations in Fig.1. Performance is comparable to [1] while requiring less memory.

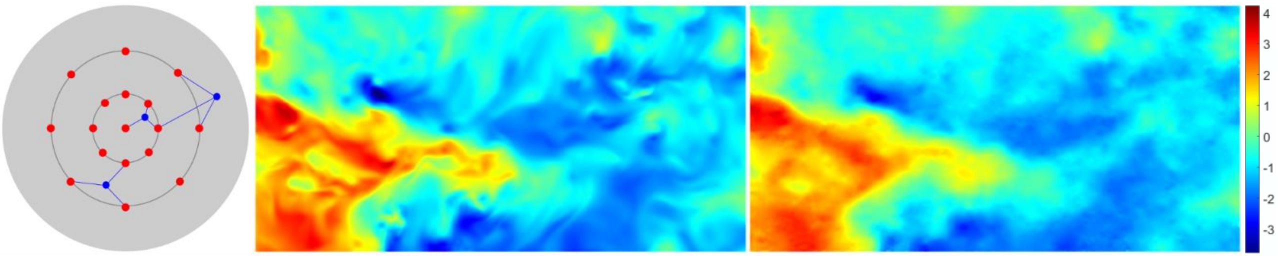

Fig. 1 Left: Schematic visualization of a 2D sparse descriptor with descriptor grid points (red) and particle locations (blue) whose intensities are splatted to the three nearest neighbors. Middle: xy-slice of the flow in X-direction for DNS simulated flow field (1024x512x352). Right: xy-slice of the reconstructed flow from approx. 0.1ppp.

References

[1] Lasinger K, Vogel C, Schindler K (2017) Volumetric Flow Estimation for Incompressible Fluids using the Stationary Stokes Equations. International Conference on Computer Vision (ICCV), Venice, Italy.