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Anisotropic and Multi-resolution RBFs for meshless Data Assimilation of scattered data

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Abstract

Image velocimetry is increasingly shifting towards tracking-based methods due to their reduced computational cost in 3D and their higher spatial resolution, which is available without modulation errors inherent to cross-correlation. However, tracking data is inherently scattered, posing challenges for post-processing tasks such as computing statistical quantities or velocity gradients. Traditional methods use binning and interpolation to map this data into structured grids to facilitate further processing, but these steps limit resolution and introduce potential errors. Recently, a framework based on physics-constrained Radial Basis Functions (RBFs) has been proposed in [1-3]. This framework uses RBF regression, constrained with physical laws such as boundary conditions or PDEs, to derive an analytic representation of the underlying data. This enables the meshless computation of derivatives and derived quantities such as pressure fields [1] and statistics [4].

The main limitation of this approach, however, is that traditional RBF regression using Gaussian bases introduces a low pass filtering effect. Moreover, in the presence of strong gradients, spurious oscillations are often observed in the regression results. This work explores two methods for overcoming both limitations. These are (1) the introduction of anisotropic bases which are tailored to the local gradients and curvature of the underlying function and (2) the introduction of multi-resolution set of bases which provides a better coverage of the wave number space. The ideas in (1) are based on basis stretching akin to the anisotropic binning proposed in [5], while the multi-resolution formulation borrows ideas from wavelet analysis. The method is tested on synthetic, numerical and experimental data, including scattered sampled from the turbulent boundary layer from the classic $Re_\tau = 1000$ DNS channel flow in the John Hopkins dataset, and a 3D particle tracking velocimetry of a round jet flow with $Re = 6750$.

Keywords:

Data assimilation, constrained Radial Basis Functions regression, Multiscale and anisotropic RBFS.

References

[1] Sperotto, P., Pieraccini, S., & Mendez, M. A. (2022). A meshless method to compute pressure fields from image velocimetry. *Measurement Science and Technology, 33*(9), 094005.

[2] Sperotto, P., Ratz, M., & Mendez, M. A. (2024). SPICY: A Python toolbox for meshless assimilation from image velocimetry using radial basis functions. *Journal of Open Source Software, 9*(93), 5749

[3] Li, L., & Pan, Z. (2024). Three-dimensional time-resolved Lagrangian flow field reconstruction based on constrained least squares and stable radial basis function. *Experiments in Fluids, 65*, 57.

[4] Ratz, M., & Mendez, M. A. (2024). A meshless and binless approach to compute statistics in 3D ensemble PTV. *Experiments in Fluids, 65*, 142.

[5] Raiola, M., Lopez-Nuñez, E., Cafiero, G. & Discetti, S. (2020). Adaptive ensemble PTV. Measurement Science and Technology , Vol. 31, No. 8