The Journal of Open Source Software

PyLogGrid: A Python package for fluid dynamics on logarithmic lattices

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DOI: 10.xxxxxx/draft

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Editor:

Submitted: 23 November 2023
Published: unpublished

The authors contributed to this work in unequal proportions, with Amaury Barral taking the lead in the majority of the research, while the remaining authors made valuable but comparatively minor contributions.

Summary

PyLogGrid is a framework to perform and analyze log-lattice simulations, as introduced by Martins (2019).

Accurate simulations of fluid dynamics, such as Direct Numerical Simulations (DNS), become prohibitevely costly as we increase the inertial range. This is in particular a problem in simulating either the dynamics of singularities, or that of geophysical and astrophysical systems. Sparse simulation models, such as shell models (Biferale, 2003; Gloaguen et al., 1985) or REWA (Grossmann et al., 1996), offer a cost-effective way to simulate such equations, by only considering a subset of the degrees of freedom, but at the cost of physical fidelity. Log-lattices (Martins, 2019, 2022) are a sparse model which conserves symmetries of the mathematical operators in a better way than previous methods.

Statement of need

A minimal Matlab framework by Campolina (2020) already exists, but it relies on proprietary software, and its capabilities are limited. PyLogGrid was designed to offer a solid, open-source, and extensive framework to perform log-lattice simulations. It enables both simulation, analysis and visualisation of log-lattice data. The choice of Python+C offers both great flexibility and speed. PyLogGrid offers sigificantly more options than Campolina (2020), including several solvers, support for $k_i = 0$ modes, failsafe simulations, optimized save formats, tests and documentation, etc.

PyLogGrid has been used in a number of publications (Barral & Dubrulle, 2023; Costa et al., 2023; Pikeroen et al., 2023).

Basic features

This corresponds to version 2.2.1.

The basics of PyLogGrid consists in a `Solver` class to simulate equations on log-lattices, and a `DataExplorer` class to visualize and analyze resulting data.

Solving equations uses rkstiff (Whalen et al., 2015) by default. Convolutions are optimized in C, can be multithreaded, parallelized, and use AVX. Simulations can be interrupted and resumed, and the grid size is adaptative. Equations are easy to write as a number of mathematical operators are available through `pyloggrid.LogGrid.Grid.Math`.

Several libraries in `pyloggrid.Libs` provide helper functions for different use cases such as I/O, data science, and (interactive) plotting. Data visualization is also multithreaded.

Availability and documentation

PyLogGrid can be installed via Pypi using `pip install pyloggrid`. Its documentation is hosted on readthedocs, and includes a tutorial.

Acknowledgements

We thank A. Mailybaev, C. Campolina for stimulating discussions and minor contributions.

Funding

This work received funding from the Ecole Polytechnique, from ANR EXPLOIT, grant agreement no. ANR-16-CE06-0006-01 and ANR TILT grant agreement no. ANR-20-CE30-0035.

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