Reconstruction of temperature and heat flux from Thermal Large Eddy Simulations using Deep Learning

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Accurately capturing velocity-temperature coupling in turbulent, anisothermal flows, such as those inside concentrated solar power towers, is critical for industrial design. While Thermal-Large Eddy Simulation (T-LES) resolves large-scale thermal fluctuations at a lower cost than Direct Numerical Simulation (DNS), it is prone to error on second order turbulent statistics. This study develops and compares three different machine learning methods to reconstruct temperature fluctuations by inverting the T-LES filter.

First, a supervised learning approach based on the work of Lapeyre *et al.* [2] is proposed. This method reconstructs the raw temperature data, and generalizes this reconstruction on the validation set, although this method is bound to paired T-LES-DNS time steps, and is thus limited to *a priori* data. To enable reconstruction on unpaired or *a posteriori* data, we introduce a weakly supervised learning method that relies on the two-point temperature correlation. The final proposed method implements a physics-constrained framework using the Adaptive Local Deconvolution Method [1, 3] optimized against temperature variance. This third approach enables the reconstruction on both *a priori* and *a posteriori* data.

[1] R. von Kaenel, N. Adams, L. Kleiser, J. Vos. *The approximate deconvolution model for large-eddy simulation of compresible flows with finite volume schemes.* J. Fluids Engng, **125**, 375–381, 2003.

[2] C. J. Lapeyre, A. Misdariis, N. Cazard, D. Veynante, T. Poinsot. *Training convolutional neural networks to estimate turbulent sub-grid scale reaction rates.* Combustion and Flame, **203**, 255–264, 2019. doi :10.1016/j.combustflame.2019.02.019.

[3] S. Stolz, N. Adams. *An approximate deconvolution procedure for large-eddy simulation.* Phys. Fluids, **11(7)**, 1699–1701, 1999.

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