Deep Learning for Flow Imaging and Spatiotemporal forecasting

Filippos Sofos[1,2,*] and Dimitris Drikakis[1]

[1]*Institute for Advanced Modelling and Simulation, University of Nicosia, Nicosia, CY 2417, Cyprus*

[2]*Condensed Matter Physics Laboratory, Department of Physics, University of Thessaly, Lamia 35100, Greece*

This paper explores advancements in super-resolution techniques for flow imaging, focusing on both spatiotemporal forecasting and flow image reconstruction through streamlined and effective methods. We introduce the UBranch algorithm, an innovation built upon the U-Net prototype, designed to facilitate both spatial reconstruction and temporal forecasting in flow fields. UBranch employs convolutional neural networks to circumvent the complexity and computational demands associated with long-short-term memory networks. This strategic design enables the model to accurately predict four future time frames from sequences of two-dimensional flow images, achieving low root mean square error and pinpointing critical maximum pressure points essential for analyzing shock-wave interactions.

Additionally, we present a deep learning-based super-resolution framework aimed at transforming coarse, turbulent flow fields into highly detailed continuous representations, particularly within the context of airflow ventilation in indoor settings. By leveraging large eddy simulations, the model uses scaled-down temperature data for training and testing, proficiently mapping these coarse fields to their high-resolution counterparts. The model's performance excels with input images scaled down by factors of 5-20, surpassing traditional linear and bicubic interpolation methods. This super-resolution technique emulates the process of sparse sensor measurement expansion to dense fields, providing a high-performance, cost-effective alternative that reduces the necessity for extensive sensor arrays. The significant improvement in spatial temperature reconstruction highlights its potential applications in fluid mechanics and related disciplines.

Keywords: Deep Learning, Fluid Mechanics, Machine Learning

References:

1. Sofos, F., Drikakis, D. and Kokkinakis, I.W., 2024. Comparison of super-resolution deep learning models for flow imaging. Computers & Fluids, 283, p.106396.

2. Sofos, F., Drikakis, D., Kokkinakis, I.W., Deep learning architecture for sparse and noisy turbulent flow data. Physics of Fluids, 2024, 36(3), 035155.

---

* fsofos@uth.gr