Synthesis of preferential concentration of particles in isotropic turbulence using neural networks

T. Maurel–Oujia[a], S. S. Jain[b]
K. Matsuda[c], K. Schneider[a], J. West[d] and K. Maeda[b]

Cluster and void formation are key processes in the dynamics of particle-laden turbulence. In this study, to extend the work of Oujia et al[1], different data-driven machine learning (ML) techniques are proposed and evaluated for synthesizing the number density field of particles in turbulence from the enstrophy of the carrier fluid. The database of 2D and 3D direct numerical simulation (DNS) of homogeneous isotropic turbulence with one-way coupled inertial point particles is used for training the model. We compare the performance of autoencoder, U-Net, generative adversarial network (GAN), and diffusion model techniques, examining the statistical properties of the generated fields. Figures 1a and 1b show respectively, 2D slices of the enstrophy and particle density for the particle Stokes number of unity obtained from the DNS. Figure 1c shows the predicted particle density using the GAN. Favourable results are obtained with GANs, showing pronounced clusters and voids, similar to those observed in the DNS data. Furthermore, we investigate the inverse problem of synthesizing enstrophy fields using particle density distribution as input for various particle Stokes numbers. Hence, this study highlights the potential for ML techniques to predict turbulence features using experimental inertial particle measurements as well as reducing the computational cost of expensive DNS computations by avoiding the tracking of billions of particles, paving the way for further research in this domain.

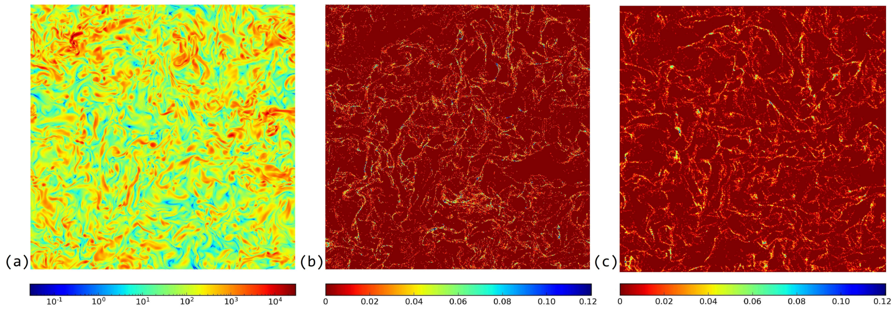

Figure 1: (a) Input enstrophy and (b) particle density corresponding to DNS data. (c) Particle density predicted from enstrophy using GAN.

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[a] Institut de Mathématiques de Marseille, Aix-Marseille Université, CNRS, Marseille, France
[b] Center for Turbulence Research, Stanford University, CA, USA
[c] Japan Agency for Marine-Earth Science and Technology (JAMSTEC), Yokohama, Japan
[d] Department of Mechanical Engineering, Stanford University, CA, USA

[1] Oujia et al., Center for Turbulence Research, *Proceedings of the Summer Program*, (2022)