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Paper Review - Machine Learning the Kinematics of Spherical Particles in Fluid Flow

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Numerous efforts have been devoted to the derivation of equations describing the kinematics of finite-size spherical particles in arbitrary fluid flows. These approaches rely on asymptotic arguments to obtain a description of the particle motion in terms of a slow manifold. Here we present a novel approach that results in kinematic models with unprecedented accuracy compared with traditional methods. We apply a recently developed machine learning framework that relies on (i) an imperfect model, obtained through analytical arguments, and (ii) a long short-term memory recurrent neural network. The latter learns the mismatch between the analytical model and the exact velocity of the finite-size particle as a function of the fluid velocity that the particle has encountered along its trajectory. We show that training the model for one flow is sufficient to generate accurate predictions for any other arbitrary flow field. In particular, using as an exact model for trajectories of spherical particles, the Maxey–Riley equation, we first train the proposed machine learning framework using trajectories from a cellular flow. We are then able to accurately reproduce the trajectories of particles having the same inertial parameters for completely different fluid flows: the von Karman vortex street as well as a two-dimensional turbulent fluid flow. For the second example we also demonstrate that the machine learned kinematic model successfully captures the spectrum of the particle velocity, as well as the extreme event statistics. The proposed scheme paves the way for machine learning kinematic models for bubbles and aerosols using high-fidelity DNS simulations and experiments.