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Generative prediction of flow fields around an obstacle using the diffusion model

[1]Jiajun Hu; [1]Zhen Lu*; [1, 2]Yue Yang*;

[1]*State Key Laboratory for Turbulence and Complex Systems, College of Engineering, Peking University, Beijing 100871, China*

[2]*HEDPS-CAPT, Peking University, Beijing 100871, China*

Abstract

We propose a geometry-to-flow diffusion model that utilizes obstacle shape as input to predict a flow field around an obstacle. The model is based on a learnable Markov transition kernel to recover the data distribution from the Gaussian distribution. The Markov process is conditioned on the obstacle geometry, estimating the noise to be removed at each step, implemented via a U-Net. A cross-attention mechanism incorporates the geometry as a prompt. We train the geometry-to-flow diffusion model using a dataset of flows around simple obstacles, including circles, ellipses, rectangles, and triangles. For comparison, the CNN model is trained using the same dataset. Tests are carried out on flows around obstacles with simple and complex geometries, representing interpolation and generalization on the geometry condition, respectively. In the test set, challenging scenarios include a cross and characters "PKU". Generated flow fields show that the geometry-to-flow diffusion model is superior to the CNN model in predicting instantaneous flow fields and handling complex geometries. Quantitative analysis of the accuracy and divergence demonstrates the model's robustness.

Keywords: denoising diffusion probabilistic model, generative model, vortex shedding, wake