Physics-Informed Neural Networks for Low Reynolds Number Flow Around Circular Cylinders

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Abstract

The SURGE project began with a comprehensive investigation into Physics-Informed Neural Networks (PINNs) applications for computational fluid dynamics, specifically targeting low Reynolds number flows around cylindrical geometries. Initial research involved extensive literature review examining existing PINN implementations for low Reynolds number scenarios and flow around cylinder configurations to establish theoretical foundations and identify research gaps.

Following the literature survey, a reference study was selected focusing on flow around a cylinder at Reynolds number 5, characterized by fluid properties including density 1.0 and dynamic viscosity 0.02. The implementation utilized a neural network architecture comprising 8 hidden layers with 40 neurons each, employing a stream function formulation to compute velocity components u and v through derivative calculations. This methodology inherently satisfies the continuity equation without requiring explicit enforcement, thereby reducing computational complexity.

Initial validation experiments were conducted using reduced collocation points with 2 Adam optimization steps followed by Limited-memory Broyden-Fletcher-Goldfarb-Shanno with Box constraints (L-BFGS-B) optimization. Results demonstrated velocity profiles closely matching reference data with highly accurate pressure distributions. Subsequent testing using exact conditions from the reference paper achieved nearly identical velocity and pressure profiles, successfully validating the implementation approach.

From this point onwards we are trying to focus on systematic investigation of the methodology's validity at progressively lower Reynolds numbers and optimization strategies involving collocation point density variations and network architecture modifications. Additionally, the model is being extended from confined duct flow conditions to free stream boundary conditions to enhance applicability for external flow problems.

Keywords: Physics-Informed Neural Networks, Low Reynolds Number Flow, Cylinder Flow

Mentor Consent: This abstract has been prepared with the guidance and consent of Prof. Indranil Saha Dalal, Chemical Engineering, IITK.