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Modelling Two-Dimensional Flow Around Airfoils Using Graph Neural Networks

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Abstract

Accuracy of prediction of aerodynamic flow around the airfoils is essential in aircraft design and optimization. Traditional methods in the domain of Computational Fluid Dynamics (CFD) for simulating flows deliver high accuracy solutions but are time-intensive and computationally expensive. In this paper, we study Graph Neural Networks (GNNs) as a data-driven surrogate model approach to simulate the airfoil flow. GNNs are inherently suited for processing unstructured mesh-based data, this makes them well suited for complex aerodynamic domains. A GraphSAGE-based model is utilized to aggregate information from neighboring nodes and predict the flow characteristics. The model is trained and validated using the opensource AirfRANS dataset, which comprises high-fidelity CFD simulations of NACA 4- and 5-digit series airfoils in subsonic regime for incompressible, steady-state flows. By applying graph-based learning, the GNNs effectively generalize to unseen airfoil shapes and create velocity and pressure fields with near-CFD accuracy with reduced computational costs. The accuracy and generalization capabilities of the model are evaluated, highlighting its potential as a fast and reliable alternative for rapid aerodynamic analysis and optimization.

Keywords: Airfoil Aerodynamics; Computational Fluid Dynamics (CFD); Data-Driven Flow Prediction; GraphSAGE; Reynolds-Averaged Navier-Stokes (RANS)