A Novel Discretized Framework for Enhanced Computational Fluid Dynamics Simulations in Turbulent Regimes

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Abstract. In the realm of computational fluid dynamics (CFD), resolving complex turbulent flows remains a significant challenge due to their multifaceted nature and dependence on numerous parameters. This study introduces a discretized framework designed to optimize simulation accuracy and computational efficiency. By integrating advanced turbulence modeling with machine learning techniques, our approach refines predictive capabilities in turbulent flow scenarios. Comprehensive validation against experimental data demonstrates the framework's superior performance over conventional methods. The findings indicate substantial reductions in computational time while maintaining high fidelity in results, enabling practical applications in engineering and environmental studies.

Keywords: computational fluid dynamics, turbulence modeling, machine learning, discretized framework, simulation optimization, predictive performance, engineering applications, environmental studies

Introduction

The increasing complexity of fluid dynamics simulations, particularly in turbulent regimes, poses substantial challenges in both academic research and industrial applications. Turbulent flows, characterized by chaotic and irregular motion, play a critical role in various fields including aerospace, mechanical engineering, and environmental science. With the demands for accurate modeling and predictions rising, traditional computational fluid dynamics (CFD) methods often fall short due to limitations in handling the intricate interactions present in turbulent flows. As we advance into 2024-2026, the necessity for innovative methodologies that enhance predictive accuracy while optimizing computational resources becomes more pronounced. This paper addresses these challenges by presenting a novel discretized framework aimed at improving simulation outcomes in turbulent conditions. Our approach leverages advanced turbulence modeling in conjunction with machine learning algorithms to enhance the predictive performance of CFD simulations. The framework not only seeks to provide more accurate representations of turbulent flows but also aims to reduce computational burdens associated with high-fidelity simulations. To demonstrate the efficacy of our proposed method, we conducted a series of experiments, comparing results with existing CFD techniques. The findings highlighted significant improvements in both computational time and fidelity, suggesting a paradigm shift in how turbulent flows can be modeled and understood. This structure of the paper will unfold as follows: we will first review the existing literature on CFD and turbulence modeling, followed by a detailed explanation of our novel framework, methodologies employed, and results obtained from various simulations. Finally, we will discuss the implications of our findings and propose directions for future research in the field.

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