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Fine-tuning a foundation model on multiphase problems

[1]*Sahba Zehisaadat*;* [1]*Steffen J. Schmidt;* [1]*Nikolaus A. Adams;*

[1]*Chair of Aerodynamics and Fluid Mechanics, School of Engineering and Design, Technical University of Munich*

Abstract

In recent years, Machine Learning (ML) models have shown great promise in learning partial differential equations (PDEs), which describe various physical phenomena in Computational Fluid Dynamics (CFD). Solving CFD problems often requires high spatial and temporal resolutions, making computations extremely expensive. Additionally, generating large datasets for problems involving multiple phases and discontinuities is challenging, and such limitations have motivated the adoption of ML. Given the scarcity of datasets, fine-tuning pre-trained Foundation Models has gained significant attention. Studies indicate that fine-tuning such models can outperform training from scratch, mainly when data is limited.

Poseidon, a foundation model based on a multiscale operator transformer for solving PDE operators, has recently been introduced. Its pre-training datasets encompass operators defined on compressible Euler and incompressible Navier-Stokes equations. Current research focuses on multiphase compressible problems, particularly cavitation bubble collapse in free field, treated as an out-of-distribution downstream task. The study evaluates Poseidon's ability to generalize to unseen physical phenomena. Moreover, it is planned to add a more advanced problem— multiple bubble interactions in free field— to further assess the model's capacity to handle complex phenomena. This study also focuses on the careful preparation and preprocessing of fine-tuning data, as well as identifying and implementing necessary modifications to comprehensively optimize model performance.

In this research, Poseidon is benchmarked against the Fourier Neural Operator (FNO), which is trained from scratch. Earlier work highlights the superior performance of FNOs over other neural operators. To address data limitations, techniques such as all2all training are employed.

Keywords: Transfer Learning, Fine-tuning, Foundation Models, Multiphase Problems