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CORRECTING THE DISCRETIZATION ERROR OF COARSE GRID CFD SIMULATIONS WITH MACHINE LEARNING

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In Computational Fluid Dynamics (CFD), approximate solutions of the Navier-Stokes equations are obtained using discretization methods on computational grids. The design of such grids has a significant influence on the accuracy of the approximate solution. While a refined grid improves the accuracy in general, this directly leads to increased computational cost. It is best practice to conduct grid convergence studies to quantify the discretization error on coarser grids and to find the optimal trade-off between cost and accuracy. However, obtaining grid converged results for full aircraft configurations at flight Reynolds numbers is often regarded as infeasible in an industrial setting, where it is not uncommon to use grids with several hundred million points. Under these conditions, it is often impossible to conduct rigorous grid convergence studies.

The goal of this work is to create a machine learning (ML) model which is able to learn and predict the discretization error between the solutions on coarse grids and the corresponding fine grid solutions, similar to [1]. The refined grid solution is mapped onto the coarse grid, which serves as ground truth for the ML algorithm. The features are derived from the coarse grid solution at each cell. Three different learning algorithms with varying complexity are tested: Random Forest, Neural Networks and Graph Neural Networks. After the supervised training, the learned model receives a new coarse grid solution and has the potential to approximate the corresponding fine grid solution with the prediction of the discretization error.

The turbulent flow over the two-dimensional RAE2822 airfoil is used to demonstrate the proposed strategy. The fine grid consists of 1280x256 cells, the coarse grid of 80x16 cells. The generalization capability is assessed by varying flow parameters.

Preliminary results for which the angle of attack and Mach number are varied show that both models are able to predict a discretization error qualitatively comparable to the ground truth, even for coarse grid simulations exhibiting divergence. Physical phenomena such as the shock locations are preserved and can be corrected if needed. Quantitatively, the lift and drag coefficients are assessed. The advantage of the proposed method is that the models are applied to each cell separately. This is not the case for convolutional neural networks commonly used for the similar purpose of super-resolution. Therefore, the trained models are applicable to unstructured grids without a pre-defined restriction on the number of cells during training or prediction. Further investigations will be made by conducting a parameter study with varying angles of attack and geometries.

REFERENCES

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