A Machine Learning based Expert System for Optimizing CFD Solver Parameters

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Computational fluid dynamics (CFD) is a valuable tool in the field of aerodynamics that complements wind tunnel testing and minimizes the time, effort and budget needed for experimental testing. Although CFD is powerful, it is a highly nonlinear and complex tool to manage efficiently as a user. Its complexity lies in the substantial number of parameters that need tuning, heavily contributing to the steep learning curve that newcomers face while also challenging experts in complex cases. This could hinder the fast and efficient approach to design and analysis that a CFD software tries to achieve. In this paper, an expert system, using a machine-learnt (ML) approach applied to CFD, is proposed. This system is responsible for tuning the solver parameters without user intervention.

The expert system is divided in two macro steps, the surrogate model and the genetic algorithm macros. The surrogate model uses a database containing various CFD simulations with different setups, each evaluated with a scoring function that calculates the efficiency, robustness, and accuracy of the simulation. The database is used to train a machine learning algorithm that is capable of evaluating the 'fitness' of future simulations. Subsequently, the Genetic Algorithm (GA) uses the aforementioned trained ML algorithm as a surrogate model that optimizes the set of solver parameters. In other words, the GA produces, in each generation different combinations of solver parameters which is then evaluated by the surrogate model and gives back to the GA their respective fitness. The end result is plotted in form of a pareto front, and therefore the set of optimal solver parameters (for a given physical problem) is concluded. This approach is demonstrated on the simple but representative NACA0012 test case in the study of optimal CFL solver parameters with the variation of Mach number and angle of attack in the framework of CODA (the next-generation flow solver, which is being developed jointly by ONERA, DLR, Airbus and other partners).

This paper extends the concept of machine learnt expert system to the field of CFD. The applied methodology allows users to find optimal solver parameters without losing valuable time in reiteration. It also allows experts to find solutions to unresolved CFD problems.

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