Optimization of large scale physical simulations using machine learning

Overview

In collaboration with a leading car OEM that heavily relies on simulations due to the absence of a wind tunnel, we embarked on optimizing large-scale CFD simulations using machine learning methods. Recognizing the computational intensity and dependence on parameters in both CFD and machine learning, techniques like Orthogonal arrays and BOHB were integrated to create a streamlined workflow for effective CFD simulation optimization.

Keywords

high-performance computing (HPC)
computational fluid dynamics (CFD)
design of experiment (DoE)
optimization
hyperparameter optimization

Situation

Akin to machine learning model training, CFD simulations are resource-intensive and hinge heavily on (hyper)parameters, making them costly and time-consuming. Given the rapid advancements in hyperparameter optimization techniques in machine learning, we hypothesized that similar methods could be applied to CFD to achieve enhanced efficiency.

Requirements

Collaborate closely with the car OEM to understand their specific simulation needs and challenges.

Identify machine learning methods suitable for hyperparameter importance discovery in the context of CFD simulations.

Understand the parallels between CFD simulations and machine learning model training, especially in terms of computational cost and parameter reliance.

Test and validate machine learning methods, like Orthogonal arrays and BOHB, in the CFD environment.

Develop a workflow that integrates these methods seamlessly into the CFD simulation process for the car OEM.

Solution

By working closely with the car OEM and leveraging techniques such as Orthogonal arrays and BOHB – originally developed for machine learning hyperparameter optimization – a tailored workflow was established for their CFD simulations. This workflow integrated the essence of rapid machine learning method development, ensuring that CFD simulations for the car OEM benefited from the latest advancements in hyperparameter optimization.

Benefits and Results

- Achieved a more efficient and cost-effective process for conducting large-scale CFD simulations for the leading car OEM.
- Demonstrated the applicability of machine learning techniques, initially designed for a different domain, in optimizing CFD processes for automotive applications.
- The newly developed workflow reduced computational resources required, thus leading to savings in terms of time and capital for the car OEM.
- Validated the belief that methods from one domain (machine learning) can be successfully transplanted to another (CFD) to achieve optimization.
- Opened up possibilities for further cross-domain applications, showcasing the adaptability and potential of machine learning techniques in the automotive industry.