Data-driven prediction of flow parameters in a ventilated cavity using high-fidelity CFD simulations

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1 Aim and Approach

In this work, we elaborate data-driven models for predicting the flow parameters in a three-dimensional ventilated cavity with a heated floor. It was first studied experimentally by Blay *et al.* [1]. Cold air enters the cavity through the inlet at the top of the left wall. The air is discharged at the bottom of the right wall. The bottom wall is hot, while other walls are cold. This configuration is typical for many indoor environmental applications.

This work aims to develop an affordable data-driven model, which accurately predicts the airflow parameters. The predictions of the model are based on the results of high-fidelity computational fluid dynamics (CFD) simulations. The elaborated model could be considered a cheaper alternative for CFD in indoor environmental design and control. The input parameters for the model are the results of CFD simulations with different geometrical aspect ratios, boundary, and initial conditions. The CFD simulations are conducted using an in-house code [2] with symmetry-preserving finite volume discretization on staggered grids. This numerical configuration has provided the best trade-off between the computational cost and accuracy in our previous studies [3, 4]. We compare artificial neural networks (ANN) with support vector regression (SVR) and gradient boosting regression (GBR) using open-source libraries.

2 Scientific Innovation and Relevance

CFD is a reliable tool for indoor environmental applications. However, accurate CFD simulations require large computational resources, whereas significant cost reduction can lead to unreliable results. The high cost prevents CFD from becoming the primary tool for indoor environmental simulations. Our previous findings [3, 4] suggest that the growth of computational resources in the near future would not be enough to make CFD available for routine use in building applications. This means more work is required on developing better models and numerical methods, to reduce the computational cost of the simulations while maintaining accuracy. In our work, we develop machine learning algorithms based on data from previous CFD simulations. The algorithms aim to accurately predict the airflow parameters while having lower than CFD computational cost. The main focus of our research is on investigating the capabilities and limitations of machine learning algorithms as a cheaper alternative to CFD simulations. In our work, we compare the computational cost and accuracy of different machine learning algorithms for the prediction of flow parameters in a ventilated cavity.

3 Preliminary Results and Conclusions

We consider a characteristic test case of turbulent ($Ra = 2.4 \times 10^9$) mixed convection in a ventilated square cavity. In the previous work [3, 4], we analyzed this test case using different turbulence models, discretization techniques, and mesh resolutions. This test case is difficult to be solved accurately due to the small aspect ratios of the inlet and outlet openings. The LES simulation with staggered symmetry-preserving discretization provided the best trade-off between computational cost and accuracy, while the accuracy of the RANS turbulence model appeared to be insufficient. Reliable, high-fidelity CFD simulations require significant computational resources, thus alternative methods of obtaining high-fidelity simulation results with lower computational cost should be explored. We use the obtained results as the guidance for the turbulence model and the discretization method choice for the CFD simulations, which form the basis of our data-driven model. Moreover, the performed analysis allows investigating the requirements for the minimal set of simulations to build up a reliable data-driven model, such as the quality of CFD (high-fidelity or coarse-grid), the number of datasets, and the principal data components, which affect the prediction the most.

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