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Machine Learning Based Intelligent CFD Surrogates for Interactive Design Exploration of Built Environments

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Abstract

When designing the built environment, engineers must consider many factors such as thermal comfort and energy efficiency, these are all directly related to ventilation/airflow. Previous work on thermal comfort has been done suggesting that temperature which deviates too far from room temperature causes a decrease in mental performance. Ventilation is also of great concern, insufficient ventilation in enclosed environments causes pollutants to be built up such as CO2 creating stale air. Showing the importance of incorporating fluid flow early in the design process, this may be difficult using traditional CFD due to being computationally expensive. A way around this is to create a machine learning (ML)-based surrogate model. Once this model has been trained, the surrogate can generate new flow fields for unseen boundary conditions in seconds.

Similar work has been done in the past including interactive aerodynamics of 3D structures and flows analysing the hemodynamics of blood flowing through arteries. This work will build on these methods for the built environment while using reduced order models (ROMs) and testing different ML methods such as GPRs. This work uses a less well-known ROM technique functional principal component analysis (FPCA) and predicts the eigenfunctions and coefficients. This is important as using ROMs has been shown to decrease training time with a loss of accuracy but keeping the dominant flow features.

The results so far have shown that FPCA can capture a larger range of variations with fewer components. When reconstructing the flow, FPCA is more accurate compared to POD both struggle as the flow develops. Future work will focus on increasing this accuracy, this will be done by testing different methods, such as testing to make sure the orthogonality of the components is not lost and creating a neural network with a unique loss function that considers this orthogonality.

Keywords: Built Environment, Reduced Order Modelling, Functional Principal Component Analysis, Surrogate, Machine Learning