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Title

Data-driven multi-fidelity surrogate models for Rocket Engines injector design

Authors

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Abstract

A change in paradigm has been experienced in the development of rocket engines, with an enhanced focus in cost-effectiveness. Additionally, new mission requirements are expected in the future, thus posing a threat for vectors with inadequate propulsive elasticity. Future estimates hence predict a competitive commercial launch and space transportation sector.

The design of new rocket propulsion systems is therefore under the growing pressure of reducing development costs. Validated high-fidelity numerical simulations, such as Large Eddy Simulations (LES) for the reconstruction of the flow field within rocket combustion chambers can play an important role in this context. These provide a relative low-cost alternative to experiment-driven design. Nonetheless, a holistic approach for design optimization is not yet practical, as conventional optimization algorithms require a great number of evaluations, which renders the problem itself intractable. A common avenue followed by industry to avoid this conundrum is to develop and implement surrogate models. These, used appropriately, provide fast inference times without significant loss in predictive accuracy.

In this work, we lay the focus on the liquid rocket engine injector. The injectors are a key constituent in liquid rocket engines (LREs) as they are responsible for introducing and mixing the propellants into the combustion chamber, hence strongly impacting the flame development and combustion efficiency. A database of ~ 100 low-fidelity LES simulations of shear-coaxial injectors, operating with a gaseous oxygen-methane mixture, has been created with the AVBP solver [1]. The design of experiments explores three variables: the chamber radius, the recess-length of the oxidizer post and the mixture ratio. In [2], Convolutional Neural Networks (CNNs) were trained upon this dataset to provide reasonable approximations of the temporal-averaged 2D flow-field.

Although neural networks are efficient non-linear data emulators, in purely data-driven approaches their quality is directly impacted by the precision of the data they are trained upon. Hence, in the current work, we develop multi-fidelity surrogate models by leveraging transfer learning methods. For such, a high-fidelity dataset has been created, albeit small, to a much greater cost per sample. The amalgamation of low and high-fidelity data during the training process enables the improvement if the surrogate models fidelity without excessive additional cost.

References

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