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Learning and Inference assisted by Feature Space Engineering (LIFE): A generalizable approach for data-driven augmentation of Physical Models

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This work presents a formalism to improve the predictive accuracy of turbulence models by learning generalizable augmentations from sparse data. The proposed approach, referred to as Learning and Inference assisted by Feature Engineering [1] (LIFE), is based on the hypothesis that robustness and generalizability demand a meticulously-designed feature space that is informed by the underlying physics, and a carefully constructed features-to-augmentation map. The critical components of this approach are : (1)Identification of relevant physics-informed features in appropriate functional forms to enable significant overlap in feature space for a wide variety of cases to promote generalizability; (2) Explicit control over feature space to locally infer the augmentation without affecting other feature space regions, especially when limited data is available; (3) Maintaining consistency across the learning and prediction environments to make the augmentation case-agnostic; (4) Tightly-coupled inference and learning by constraining the augmentation to be learnable throughout the inference process to avoid significant loss of information. The impact of various ways of discretizing the feature space is carefully assessed. This approach is used in the modeling of bypass transition and shock-turbulence interactions, targeting generalizable predictions of heat flux, surface heat transfer and skin friction.

REFERENCES

[1] Srivastava, V., & Duraisamy, K., Generalizable Physics-constrained Modeling using Learning and Inference assisted by Feature Space Engineering, Physical Review Fluids, 2021.