A Framework for Turbulence Modeling Using Big Data

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Assessments performed by NASA have identified deficiencies in the representation of turbulence as the most severe obstacle to realize predictive computational simulations of problems of relevance to the aerospace community. Recent efforts to define the requirements for a NASA Vision 2030 CFD solver have focused on the need for significantly improved turbulence and transition models that currently prevent truly physics-based predictions of fluid flow.

Even with significant advances in computing power, Reynolds Averaged Navier-Stokes (RANS) based representations of turbulence will continue to be the only practical paradigm for the engineering simulation of boundary layer flows over complex surfaces. Over the past 50 years, turbulence modeling has evolved through a combination of theory, empiricism, mathematics and though tremendous progress has been made, these models are incapable of performing consistently well in complex flows. The general impression within the turbulence modeling community is that ideas for improved RANS modeling have completely stagnated, especially over the past decade.

A new and more effective paradigm is needed to cause a shift away from the status quo. Our key focus is the creation and demonstration of a framework to utilize large-scale data-driven techniques to enable the construction of accurate models of turbulence. This will require the development of domain-specific learning techniques suited for turbulence, the establishment of a trusted ensemble of data for the creation and validation of new models, and the deployment of these models in complex aerospace problems for which RANS models have failed in the past. It is clear that the traditional approach to turbulence model development does not leverage the availability of massive amounts of data from many different sources. Yet, it seems intuitively obvious that informing the development of closure terms with a broader set of simulations can yield more broadly accurate simulations of turbulence. Our proposal thus involves the confluence of turbulence theory, computational science, and computer science.

An observation regarding the work is that our intent is not to replace decades of turbulence modeling knowledge but rather to build on that knowledge. We believe that our effort may result in radical advances in turbulence modeling with the potential to move us away from the plateau that the field has been stuck on for the better part of two decades.