Advances in deep learning for reliable and accurate digital twins in aerospace engineering.

Over the past decade, Deep Learning (DL) techniques have been extensively developed to build digital twins for a wide range of increasingly complex flow problems. However, fundamental challenges remain due to the unsteady, nonlinear, and multiscale nature of fluid dynamics. In this presentation, I will discuss how recent advances in DL have helped to address, at least partially, these challenges. First, I will present the application of Implicit Neural Representations (INR) to steady complex flows encountered in external aerodynamics and turbomachinery, highlighting the use of specific treatments to mitigate spectral learning bias. Second, an unsteady problem involving a flexible HALE (High-Altitude, Long-Endurance) drone subjected to gusts will be discussed, where enforcing time-consistency is crucial for developing an accurate digital twin. Third, I will introduce recent developments aimed at equipping deep networks with uncertainty quantification capabilities. Overall, the objective is to demonstrate how modern DL methodologies can build efficient, accurate, and reliable digital twins for aerospace engineering applications.