

Machine Learning for Fluid Mechanics and Flow Reconstruction in Engineering

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Abstract

The integration of artificial intelligence (AI) into fluid mechanics has revolutionized the study of turbulent flow structures, offering innovative methods for understanding, modeling, and solving complex flow phenomena. This lecture will present insights from my research at the intersection of AI and fluid dynamics and highlight the work conducted at my laboratory in developing AI-driven solutions to address critical challenges in fluid engineering. Beginning with a historical perspective and an overview of current trends in AI and deep learning (DL), I will demonstrate the transformative potential of advanced DL models, such as Enhanced Super-Resolution Generative Adversarial Networks (ESRGAN) and transformer architectures, in advancing fluid mechanics. Key topics will include AI-powered turbulent flow reconstruction, flow denoising, and the generation of realistic turbulent inflow conditions for simulations. I will illustrate how these DL methods enable the reconstruction of high-fidelity turbulent flow fields from sparse or noisy data, meeting essential needs in both computational and experimental fluid dynamics. In addition, I will discuss real-world applications of AI-driven fluid mechanics, including cancer suppression strategies, MPC-based PID and PLC control systems for industrial process optimization, and innovative monitoring solutions, such as systems for baby and elder care.

Keywords: AI-driven fluid mechanics, Turbulent flow reconstruction, Deep learning in fluid dynamics, Generative Adversarial Networks (GANs)

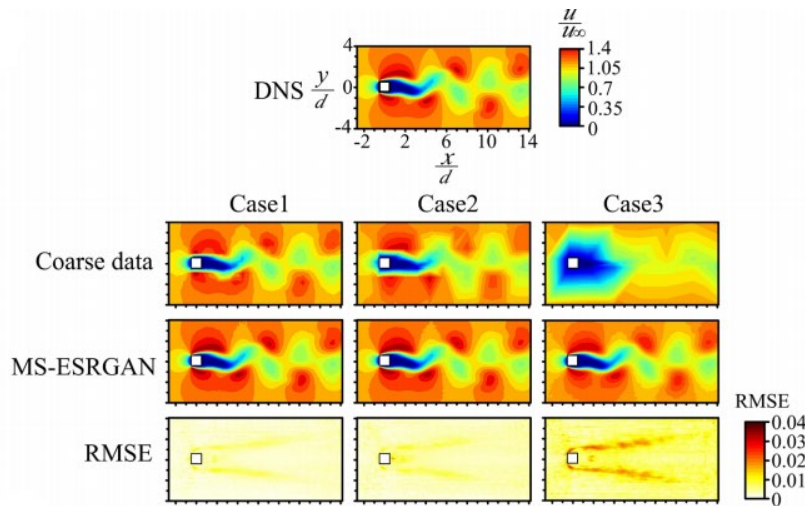


Fig. 1 Reconstructed instantaneous streamline velocity fields and RMSE for the case of turbulent channel flow at $Re_\tau = 180$

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