Mechanical Engineering Graduate Student Seminar Series - Spring 2025

Physics-Informed Neural Networks: A Novel Approach to Engineering Problem Solving

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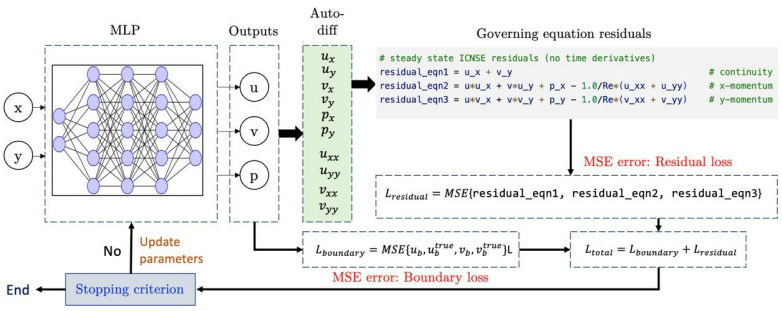
Dan Kahn 217, Sunday, 12:30-13:00, April 20, 2025

Physics-Informed Neural Networks (PINNs) are an emerging computational framework designed to solve complex engineering problems described by physical laws. By harnessing the neural networks' capability to approximate continuous functions, as formalized by the Universal Approximation Theorem, PINNs theoretically enable accurate solutions across the entire computational domain without explicit reliance on discretization. This is in contrast to traditional numerical methods, which not only rely on discretization schemes but are also limited by the order of accuracy inherent to the chosen method. Although promising, PINNs remain an evolving methodology and have yet to demonstrate consistent advantages over established numerical methods.

This seminar will introduce the fundamental concepts behind PINNs, emphasizing how they integrate deep learning with domain-specific physical knowledge. Practical aspects of implementing PINNs using modern machine learning libraries, such as PyTorch, will be covered. To illustrate the methodology, a case study will be presented, focusing on the application of PINNs to the 2D incompressible Navier-Stokes equations, specifically the lid-driven cavity problem. Additional examples, including compressible Euler equations and Maxwell's equations, will highlight the versatility of this approach.



The seminar will also address the challenges associated with PINNs, such as spectral bias and stability issues, and discuss strategies for improving accuracy and reliability. The aim is to offer a balanced perspective on the current capabilities of PINNs, emphasizing both their potential and their limitations, while identifying promising avenues for future research.

[1] Shimon is a Ph.D. candidate working under the supervision of Professors Leonid Tartakovsky and Steven Frankel. His research focuses on experimental and computational studies of combustion in rotary engines.