DEPARTMENT OF MECHANICAL & AEROSPACE ENGINEERING
WILLIAM MAXWELL REED SEMINAR SERIES

"Physics-guided machine learning: from computational mechanics to system operation"

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Abstract:
Machine Learning (ML) has recently been explored in almost every engineering discipline. Classical ML is known to have poor prediction capability as a purely data-driven approach since no physics knowledge is included. This talk presents the concept of physics-guided machine learning (PGML). The PGML methodology encodes the underlying physics of engineering problems into machine learning models and fuses information from abstracted knowledge and observed data together. Three physics-encoding methods are presented to cover the most common engineering problems: encoding in network architecture, encoding in input features, and encoding in output functions. The first method is illustrated using the multigrid convolutional neural networks (CNN)-based method for partial differential equations (PDEs), e.g., multiscale computational mechanics for materials. The second method is illustrated by encoding prior physics and knowledge in imaging quantifies to facilitate reinforcement learning for UAV path planning and conflict resolution. The last method is illustrated using air traffic management for near-terminal flow, density, and delay time prediction. These different methods are demonstrated with applications at very different scales, including material failure, control and planning, and operational management. The results show several major advantages of physics-guided machine learning: superior prediction/extrapolation capability; significant reduction of training sample requirements; fast computation, especially for nonlinear and dynamic problems; and learning results that are interpretable and trustworthy. Several limitations and future research directions are discussed based on the findings from the current study.

Speaker Bio:

Yongming Liu is a Professor in mechanical and aerospace engineering at Arizona State University and is the founding director of the Center for Complex System Safety – a joint center of Arizona State University, University of Arizona, and Northern Arizona University. He completed his Ph.D. at Vanderbilt University in 2006 and obtained his bachelor's and Master's degrees from Tongji University in China in 1999 and 2002, respectively. Dr. Liu's research interests include scientific machine learning, probabilistic methods, fatigue and fracture, imaging-based experiments, and computation and simulation. He was the recipient of the Air Force Young Investigator Award in 2011. He has worked with various governmental agencies and industrial partners for his research, including NASA, NSF, DOE, DOT, and DOD. He is currently leading a NASA University Leadership Initiative project on information fusion for air traffic management, which focuses on developing probabilistic learning methods with extensive data resources for air transportation safety assurance.

Date: Friday, April 14, 2023
Time: 3:00 PM EST
Place: Whitehall Classroom Building 110
Contact: Dr. Jesse Hoagg

Attendance open to all interested persons

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