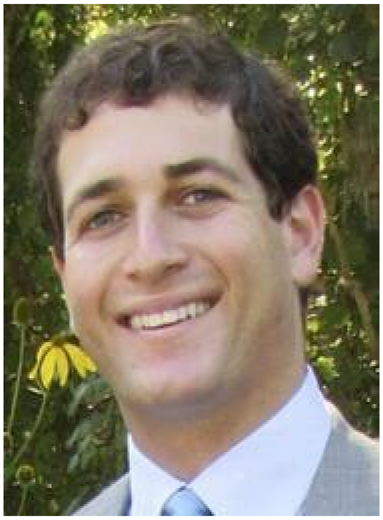
UWaterloo MME Departmental Seminar Series



GPU Acceleration for Real-Time, Whole-Body, Nonlinear Model Predictive Control

Speaker: **Prof. Brian Plancher**

Barnard College, Columbia University, USA

Theme: Robotics, Control, Optimization

Time: 2022-Nov-21, 1:00 pm - 2:00 pm

Zoom Meeting ID: 966 7094 8019 (link) Passcode: MME2022

Summary: Whole-body, nonlinear model predictive control (MPC) has been referred to as the "Holy Grail" of robot motion planning and control, as it can enable robots to dynamically compute optimal trajectories and adapt to changes in their environment. Unfortunately, the underlying trajectory optimization algorithms traditionally used to solve these problems are computationally expensive and often too slow to run in real-time. Compounding this issue, the impending end of Moore's Law and the end of Dennard Scaling have led to a utilization wall that limits the performance a single CPU chip can deliver, requiring computer scientists to look beyond the CPU to exploit large-scale parallelism available on alternative computing

platforms such as GPUs. This talk charts a path towards addressing these challenges by exposing, analyzing, an parallelism patterns found in the numerical optimization and rigid body dynamics algorithms commonly used fo careful algorithmic refactoring and re-design, this work exploits these patterns to enable real-time MPC perform

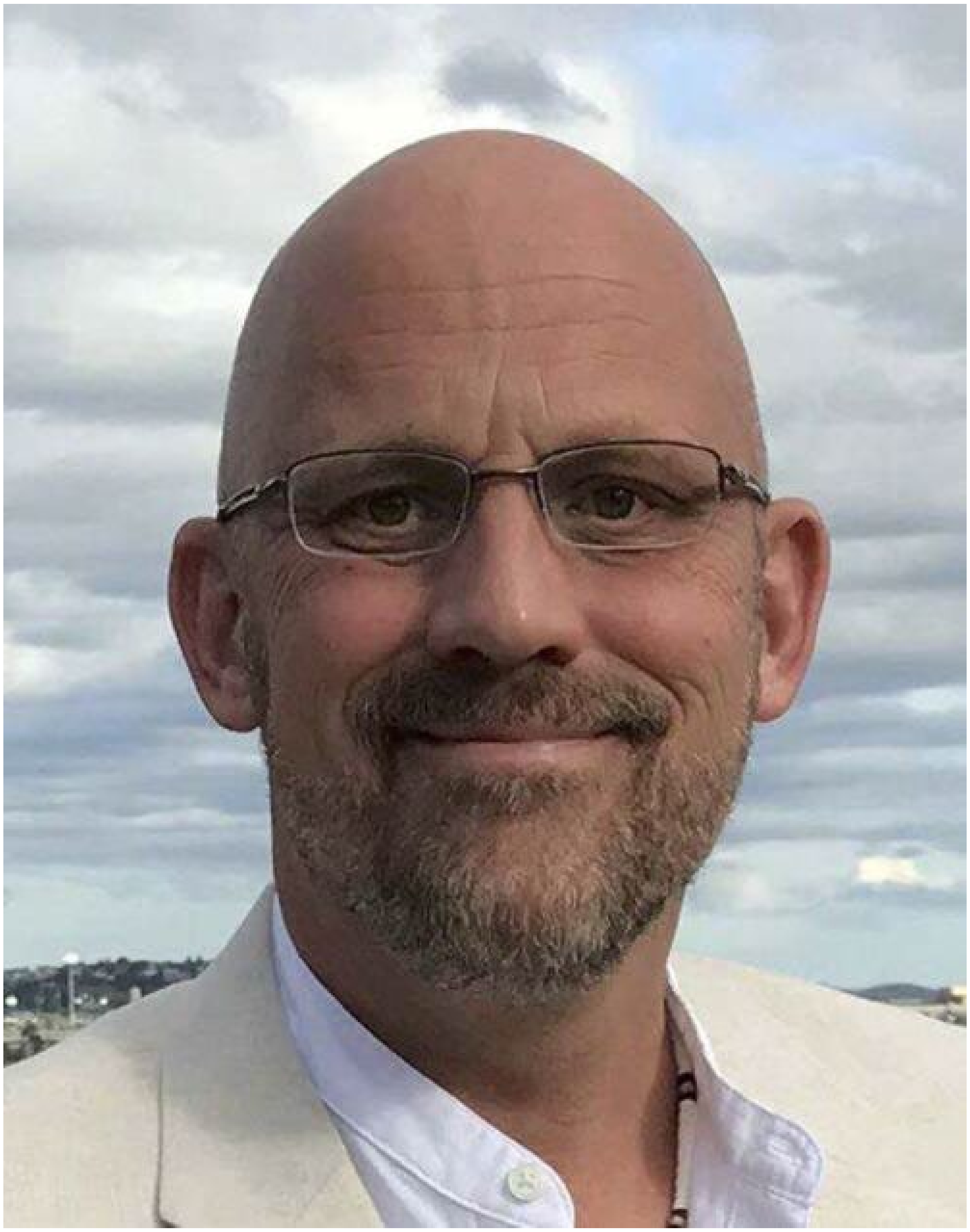
Prof. Brian Plancher is an Assistant Professor of Computer Science at Barnard College, Columbia University Accelerated Robotics Lab (A²R Lab). He also co-chairs the Tiny Machine Learning Open Education Initiative (for the IEEE RAS TC on Model Based Optimization for Robotics. His research is focused on developing and in dynamic motion planning and control of robots by exploiting both the mathematical structure of algorithms and

As such, his research is at the intersection of Robotics and Computer Architecture, Embedded Systems, Numeri
He also wants to improve the accessibility of STEM education. As such, he researches ways to better understan
and belonging in STEM education globally, as well as designs and teaches new interdisciplinary, project-based,
barrier to entry of cutting edge topics like robotics and embedded machine learning.

Please contact the host, Prof. Yue Hu (yue.hu@uwaterloo.ca), if any questions

TURBULENCE STRUCTURE AND MODELING IN THE FREQUENCY DOMAIN
Speaker: Prof. Tim Colonius
Caltech, USA
Theme: Fluid Mechanics

Time: 2022-Nov-7, 11:00 am-12:00 pm ETD
Zoom Meeting ID: 789 699 0683 (link) Passcode: MME2022



Abstract: Amongst many available data-driven modal decompositions of utility in fluid mechanics, the frequency-domain (spectral) version of the proper orthogonal decomposition (SPOD) plays a special role in the analysis of stationary turbulence. SPOD modes are optimal in expressing structures that evolve coherently in both space and time, and they can be regarded as optimally averaged DMD modes. Importantly, the SPOD spectrum is also related to the resolvent spectrum of the linearized dynamics and examination of the relationships between the SPOD and resolvent modes yields information about how coherent structures are forced by nonlinear interactions amongst coherent and incoherent turbulence. We discuss the application of these tools to analyze and model turbulence in high-speed jets and boundary layers. We highlight recent developments including (a) utilizing eddy-viscosity models in resolvent analysis to enable RANS-based prediction of coherent structures, and (b) nonlinear extensions of resolvent analysis

to discover worst-case disturbances for laminar-turbulent transition, and (c) the development fast spatial marching methods for large-scale resolvent problems.
Tim Colonius is the Frank and Ora Lee Marble Professor of Mechanical Engineering at the California Institute of Technology. He received his B.S. from the University of Michigan in 1987 and M.S and Ph.D. in Mechanical Engineering from Stanford University in 1988 and 1994, respectively. He and his research team use numerical simulations to study a range of problems in fluid dynamics, including aeroacoustics, flow control, instabilities, shock waves, and bubble dynamics. Prof. Colonius also investigates medical applications of ultrasound and is a member of the Medical Engineering faculty at Caltech. He is a Fellow of the American Physical Society and the Acoustical Society of America. He was the recipient of the 2018 AIAA Aeroacoustics Award, and the 2021 Stanley Corrsin Award from the American Physical Society.

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Please contact the host, Prof. Zhao Pan (zhao.pan@uwaterloo.ca), if any questions

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COMPUTATIONALLY DESIGN SUSTAINABLE MORPHING MATTER

Speaker: Prof. Lining Yao
Carnegie Mellon University (CMU), USA Theme: Morphing Matter, Sustainability

Time: 2022-Oct-06, 11:00 am - 12:00 pm
Zoom Meeting ID: 966 7094 8019 (link) Passcode: MME2022

Summary: A significant contributor to climate disaster is the way we make, grow and consume physical things. Sustainable morphing matter is defined as physical materials and structures that dynamically reconfigure in shapes and functions in response to natural and ambient energy stimuli.
Unlike electronic sensors and motors, the dominant machine components for "motion" and "function" in today's autonomous and robotic systems, sustainable morphing matter systems are often biodegradable and triggered by electricity-free energy stimuli, yet programmed to be adaptive, responsive, and intelligent. To elaborate many ways bio-inspired and bio- hybrid morphing systems can contribute to the global sustainability effort, the director of the Morphing Matter Lab, Dr. Lining Yao will present a few morphing systems that hold promise to contribute to sustainable agriculture, environmental conservation, and manufacturing.
Prof. Lining Yao is the Cooper-Siegel Assistant Professor of the Human-Computer Interaction Institute at Carnegie Mellon University (CMU), School of Computer Science, directing the Morphing Matter Lab (morphingmatter.cs.cmu.edu). Lining also holds courtesy appointments at Mechanical Engineering and Material Sciences and Engineering at CMU. Morphing Matter lab develops processes, materials, mechanisms, tools, and applications of adaptive, dynamic, and intelligent morphing materials from nano to macro scales. Research often combines computational fabrication, material engineering, mechanics and geometry studies, as well as human- or nature- centered design processes. The mission is to advance both science and society with the design of morphing matter.
Lining gained her Ph.D. from the MIT Media Lab. She is the co-founder of MorphingMatter4Girls Initiative, a Wired UK fellow, an appointed Instructor by the United Nation Industrial Development Organization, a CMU Provost's Inclusive Teaching Fellow, and a recipient of the NSF CAREER Award.

Please contact the host, Prof. Yue Hu (yue.hu@uwaterloo.ca), if any questions

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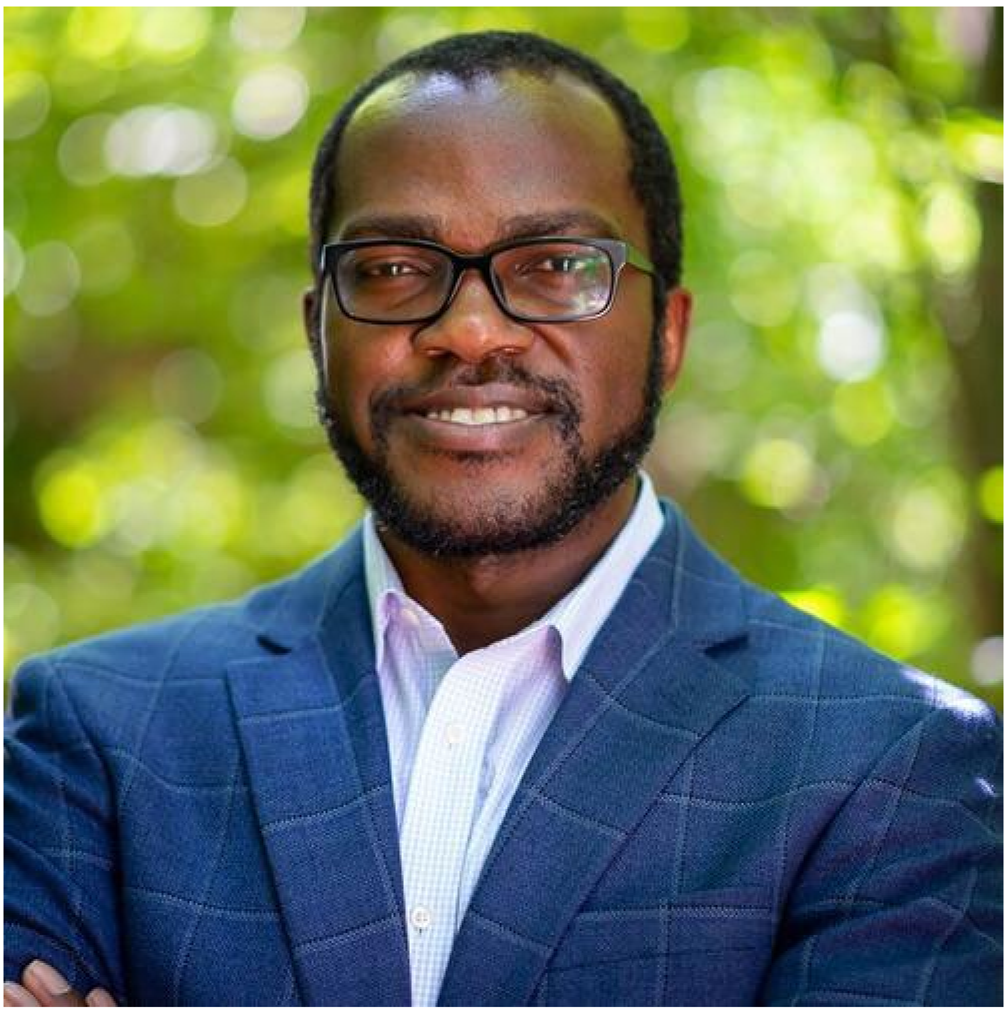
SECURING CRITICAL MATERIALS FOR EMERGING ENERGY TECHNOLOGIES IN THE U.S.
Speaker: Dr. Chukwunwike (Nwike) Iloeje, Principal Scientist
Energy Systems & Infrastructure Analysis (ESIA) Division
Argonne National Laboratory, U.S.
Theme: Energy, Materials, Manufacturing

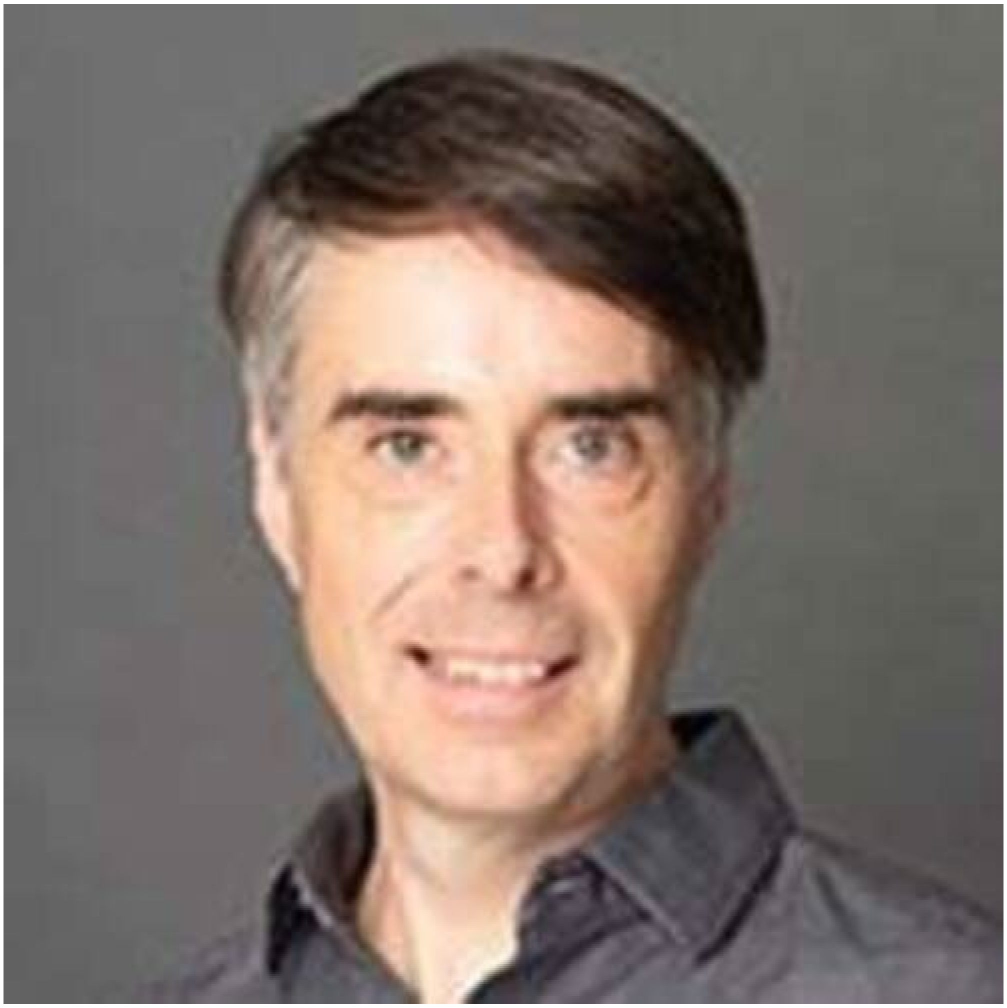
Time: 2022-Sept-26, 10:00-11:00 am EST
Zoom Meeting ID: 789 699 0683 (link) Passcode: MME2022



Summary: Critical materials such as rare earth underpin technologies needed for a decarbonized global economy. Critical materials – like rare earth elements – are essential to emerging energy technologies that underpin the US decarbonization goals. Despite having vast mineral resources, the US has limited operational mining and refining capacity, leading to net import reliance and consequent supply vulnerabilities. Secondary recovery can mitigate the supply risks and enable a circular economy for critical materials. However, feasibility depends on the technical performance, energy, economic and environmental footprint of the recovery technology when deployed at scale.
In this talk, I will give an overview of the challenge of material criticality, and the potential of secondary recovery to mitigate supply risks. Then I will show how we can address the question of feasibility with simulation and mathematical optimization, addressing the problem at various scales from process fundamentals to reverse logistics.
Dr. Nwike Iloeje is a principal scientist in the ESIA division at Argonne, and the strategic analysis group Co-Lead for the DOE-advanced manufacturing office. In his research, he uses computational modeling to explore questions at the intersection of sustainable energy conversion and material transformations, with particular interest in critical materials, carbon capture and utilization. He has a PhD from Massachusetts Institute of Technology, and Bachelors' from the University of Nigeria, both in Mechanical Engineering.

SECURING TWO PROBLEMS IN DATA ASSIMILATION FOR THE SHALLOW WATER EQUATIONS
Speaker: Nicholas Kevlahan
Department of Mathematics and Statistics,
McMaster University
Theme: Fluid Mechanics, Data Science

Time: 2022-Oct-25, 10:00-11:00 am EST
Zoom Meeting ID: 947 9123 3531 (link) Passcode: 998101



Summary: The shallow water equations (SWE) are a widely used model for the propagation of surface waves in oceans, lakes and rivers. Common applications include modelling the propagation of tsunami waves, storm surges and flooding. In this talk we describe two data assimilation problems for the SWE, both based on sparse observations of the free surface height. The goal of the first problem is to reconstruct the initial conditions for a surface wave. In the case of the relatively simple linear one-dimensional problem we prove a theorem that gives sufficient conditions on the number and spacing of the observations that ensure convergence to the true initial conditions. These results are confirmed numerically for the nonlinear equations. We then consider the associated two-dimensional nonlinear problem. We compare observations arranged in straight lines, in a grid, and along concentric circles, and determine the optimal number and configuration of observation points such that convergence to the true initial conditions is achieved. In the second (ill posed) problem our goal is to determine under which conditions observations of the free surface are sufficient to reconstruct the bathymetry to a given accuracy (e.g. sufficient for modelling wave propagation). We use density-based global sensitivity analysis (GSA) to assess the sensitivity of the surface wave and reconstruction error to model parameters and second order adjoint analysis (SOA) to derive the sensitivity of the surface wave error, given the reconstructed bathymetry, to perturbations in the observations.
Nicholas Kevlahan is a Professor in the Department of Mathematics and Statistics at McMaster

University. He has a BSc from the University of British Columbia, a PhD from the University of Cambridge and was a Marie Curie post-doctoral fellow at École Normale Supérieure (Paris). He has been an invited professor at Université Grenoble-Alpes, INRIA, École Normale Supérieure (Paris), École Polytechnique (Paris), and a visiting researcher at the University of Cambridge. His interdisciplinary research program is focused on advanced mathematical and computational methods for fluid dynamics problems from physics and engineering. Current research includes developing the WAVETRISK code for dynamically adaptive climate modelling, data assimilation techniques, fluid-structure interaction and compressive sampling. He has an active research group of PhD, MSc and BSc students from a wide diversity of backgrounds.