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THESIS DEFENSE

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5:00 PM | ABE 3054

Modeling Material Flow Dynamics in Coupled Industrial-Natural Systems: A Machine Learning Approach for Resilience and Sensor Minimization

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Understanding material flows and resilience in complex coupled industrial-natural systems, challenged by multi-scale dynamics, is vital for sustainability. This research developed a framework integrating mechanistic and data-driven techniques for system analysis, resilience quantification, and optimized sensor network design. Methods included extending Sparse Identification of Nonlinear Dynamics (SINDy), formulating hybrid mechanistic-SINDy models for bioprocesses, and key causality-guided sensor minimization using Liquid Time-Constant networks, validated across chemical, hydrological, and ecological systems. Results successfully captured emergent nonlinear dynamics and critical tipping points. A soybean-biodiesel resilience assessment under climate scenarios (RCP 4.5/8.5) quantified failure frequencies, recovery dynamics, and revealed nonlinear relationships between system configuration, climate forcing, and resilience. These methods advance industrial ecology, enabling better characterization of cross-scale interactions and supporting sustainability governance under uncertainty.

BIO

William received a joint-bachelors degree in Mechatronics Engineering and Applied Mathematics from NCSU and UNCA in 2020. He joined ABE as a PhD student in 2020, working with Dr. Shweta Singh in the Sustainable Industrial-Natural Coupled Systems (SINCS) Group. In 2022, he was awarded the National Science Foundation Graduate Research Fellowship (GRFP) to pursue research in modeling industrial-natural coupled material-flow networks. Upon completion of this research, William intends to continue applying his expertise in the modeling of complex system dynamics for informed decision-making.

Dr. Shweta Singh
Advisor

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