



DISSERTATION DEFENSE

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CIVL G212



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SEE and ESE Student

Machine Learning for Intelligent Bioprocessing of Unicellular Photosynthetic Systems

Translating biofuel technologies into commercially viable conditions is bottlenecked by bioreactors that operate as black-box systems. We know the inputs and can measure the outputs, but the intracellular dynamics in between, driving biosynthesis of biofuel-precursors molecules, remain impossible to control. There is a lack of real-time tools capable of monitoring intracellular biochemical dynamics and anticipating metabolic stress before cultures undergo irreversible shifts. Motivated by this gap, I dedicated my Ph.D. to developing an intelligent, non-destructive low-cost PAT system for early-warning detection of intracellular chlorophyll-to-lipid dominance shift in microalgal bioreactors. I wired the optical sensing hardware, configured the bioreactor platforms, programmed the data acquisition architecture, and implemented a continuous real-time processing AI pipeline. Built upon a physics-informed, time-aware machine learning model, this pipeline is grounded in optical dynamics. It uses causal modeling of light-matter interactions and temporally structured signal deviations to infer intracellular lipid droplet formation and chlorophyll dynamics. Despite a total hardware cost of just \$270, the platform achieved predictive accuracies >90% when benchmarked against measurements obtained using \$60,000 epifluorescence microscopy instrumentation. Importantly, this system functions as an anticipatory stress detector. It identifies metabolic transitions prior to full phenotypic manifestation and enables proactive adjustment of bioprocess conditions to maintain optimal productivity. Laying the foundation for intelligent, self-driving bioreactors.

Bio

Amanda M. Lopez is a Ph.D. Candidate in Environmental and Ecological Engineering affiliated with the Interdisciplinary Ecological Sciences and Engineering Program at Purdue University. Her work bridges classical bioprocess engineering with artificial intelligence (AI) and automation as a new interdisciplinary approach to study bioprocesses. Amanda has been recognized with two awards from the U.S. Department of Energy (DOE) and has been selected for presentation at the Purdue+Google AI Summit and the AEESP Distinguished Lecture Series. She has authored multiple publications in cellular bioanalytics with a focus on application of ML/AI to bioprocess optimization. Her research interests are in transforming bioreactors from black-box systems into transparent, controllable, and ultimately self-driving platforms for bioenergy production.

Dr. George Zhou
Advisor

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