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**Ph.D. DISSERTATION DEFENSE**

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| **Degree:** | Doctor of Philosophy |
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| **Department:** | Mechanical Engineering (ME) |
| **Date:** | 07/09/2025 |
| **Time/Location:** | 11:00 AM/ Carnegie 315 |
| **Title:** | Integration of Sensor Modules and Machine Learning Methods for Real-Time Quality Monitoring in Additive Manufacturing |
| **Chairperson:** | Prof. Souran Manoochehri, Department of Mechanical Engineering, SES |
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**ABSTRACT**

Additive manufacturing (AM) has great capabilities to fabricate intricate parts through layer-by-layer material deposition. Ensuring high-quality production is a challenge due to the complexity of AM processes and the lack of effective real-time monitoring and data analysis. This research aims to address these challenges by developing comprehensive, AI-driven models for real-time monitoring, data fusion, and quality control in AM processes. This study centers on two distinct AM technologies: Fused Filament Fabrication (FFF) and Direct Energy Deposition (DED). Each machine is integrated with advanced sensor modules, including optical cameras, laser profilometers, and acoustic emission sensors. These systems capture print process datasets such as top surface point clouds, print head location, and melt pool characteristics. This study introduces several innovative methodologies for end-to-end monitoring, including autonomous anomaly detection for top surface and melt pool quality evaluations, as well as real-time process parameter adjustments using dynamically adaptive G-codes. By leveraging AI models specifically tailored to each AM technology, this research enables proactive control solutions that autonomously respond to quality deviations. Key contributions of this work include the creation of large, accessible AM datasets to support the broader research community and the development of multiple AI models for real-time process analysis. Specifically, this study introduces models such as Tunable Deep Image Processing (TDIP) and Binocular model for melt pool analysis in the metal AM, as well as a passive control system for top surface quality control in the FFF process. Additionally, a hybrid quality control system utilizing a laser engraver module for corrective measures during the FFF process is proposed. The findings and methodologies presented in this work aim to bridge the gap in real-time monitoring and control, facilitating the AM industry's transition toward AI-enabled smart manufacturing.