Ph.D. DISSERTATION DEFENSE

Candidate:	Sean Rooney
Degree:	Doctor of Philosophy
School/Department:	Charles V. Schaefer, Jr. School of Engineering & Science / Department of Mechanical Engineering
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Title:	AI for State Estimation and Diagnostics of Additive Manufacturing Machinery
Chairperson:	Dr. Kishore Pochiraju, Department of Mechanical Engineering
Committee Members:	Dr. Hongjun Wang, Department of Biomedical Engineering Dr. Hamid Hadim, Department of Mechanical Engineering Dr. Robert Chang, Department of Mechanical Engineering

ABSTRACT

Failure is common in additive manufacturing (AM) due to a lack of robustness in machinery and material uncertainty, and environmental factors. The inexpensive but popular, Fused Filament Fabrication (FFF) machinery is particularly susceptible to process failures. The common modes of FFF machinery failures are extruder collisions with a warped part, mechanical issues due to age/use, filament run out, or jam. The open-loop nature of FFF machines precludes recovery from a failed state leading to material and process time waste. This work explores a method for characterizing and diagnosing the state of the machinery commands through dynamic current draw monitoring. This method deduces the state of FFF machinery and any fault condition using Artificial Intelligence (AI) and Machine Learning (ML) classification methods. Two different current draws were monitored. The DC input into the machine's controller (when accessible) successfully classifies the filament's normal, clogged, and slack states. We further showed that the classification methods can discern the movements of individual stepper motors in the 3D printer from the current input signals. We demonstrated the method generalizes to an LCD photocuring technology printer by diagnosing delamination states. Since many printers have limited access to the DC side of the power supply, we extended our current monitoring approach to the input 110V AC line. The diagnostic method for DC measurements uses a non-invasive Hall effect sensor and a high-frequency (80KHz) Analog-to-Digital converter. This current-based printer state detection and diagnostic procedure work equally effectively in detecting filament stepper states and failures. The trained classifiers can successfully predict the operational state with a mean 85% cross-validation score when detecting filament extruder states and failure conditions. For AC measurements, a split-core current transformer is used. The methodology developed has a major impact on the efficient human supervision of 3D printer farms in large-scale manufacturing environments. Such technologies are key to transitioning from Industry 4.0 (incorporates sensing and IoT) goals to Industry 5.0, which needs the human-in-the-loop element.