ABSTRACT

Robotic-Assisted Additive Manufacturing (RAAM) represents the cutting-edge of modern manufacturing, holding the potential to revolutionize production processes by seamlessly integrating contemporary sensing techniques for real-time data collection and decision-making. The inherent capability to influence production on-the-fly offers a pathway to next-generation manufacturing characterized by continuous precision, enhanced efficiency, and improved quality. However, the nascent status of RAAM, coupled with challenges related to trajectory errors in modern robotic platforms, imposes limitations on its widespread application. This comprehensive investigation into RAAM seeks to uncover the complex landscape of additive manufacturing errors and develop strategies to enhance precision. It involves understanding the interplay between the printer's kinematics and the manufacturing process, identifying error sources, and implementing effective mitigation techniques. By proposing an augmented design framework for a cyber-physical manufacturing paradigm enhanced through metalearning principles the study successfully to establishes a series of relationships between the printer and part which minimize geometric deviations. Key results include: i) The implementation of an 99.7% accurate artificial neural network predictive tool for print error. ii) A real-time gcode-modification regime which leverages control theory shown to reduce error in linkage trajectory. iii) A kinematic optimizer for part-printer position, showing up to 89% decrease of error along the printed path, 5.13% increase in tensile strength, and near 50% decrease in void percent. Furthermore, the research introduces an innovative error reduction strategy through a material-based insitu sensing technique with accuracy comparable to state of the art infrared tracking hardware. These findings provide valuable insights into motion planning and trajectory optimization, potentially leading to reduced overall geometric error, improved physical properties, and a wider adoption of RAAM.