MUR
Dipartimento
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Research project

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Title: AI-Driven Engineering of Processing–Structure–Property Relationships in Metal Additive Manufacturing for High-Performance Materials

Description: Metal Additive Manufacturing (MAM) represents a disruptive shift in materials processing, enabling design freedom, customization, and efficient use of resources. However, widespread adoption is currently limited by insufficient control over the complex and nonlinear relationships between processing parameters, evolving microstructures, and final material properties. This project addresses this fundamental challenge by integrating Artificial Intelligence (AI)—particularly machine learning (ML) and data fusion—into the entire material development pipeline. By doing so, we aim to build an intelligent, closed-loop system that dynamically learns and optimizes the processing–structure–property (P–S–P) linkages in metallic AM.
The central premise is that coupling in situ process monitoring with multiscale materials characterization and AI-enhanced modeling can dramatically accelerate the design of MAM processes and components, improving performance, predictability, and sustainability. This research will focus on high-performance alloys processed by Laser-Based Powder Bed Fusion (LPBF), Directed Energy Deposition (DED), and Wire Additive Manufacturing (WAM). Through the development of a data-centric, AI-guided framework, the project aims to discover hidden correlations, reduce experimental loads, and enable process optimization beyond conventional trial-and-error approaches.

Objectives of research

- To collect multimodal data from MAM processes (thermal, visual, acoustic) and integrate them into a unified digital dataset using AI-enhanced data fusion techniques.
- To use supervised and unsupervised machine learning algorithms to model and predict microstructural evolution (grain morphology, texture, phase composition) from process conditions.
- To correlate microstructural features with mechanical and functional properties using AI-enabled multiscale property prediction.
- To develop a closed-loop, AI-based decision-making system for real-time process optimization and defect mitigation in MAM.

Scientific Innovation and Impact

This proposal represents a paradigm shift in metal AM by introducing AI not merely as a post-processing tool, but as a central, proactive agent embedded in the entire materials development cycle. It advances the current state-of-the-art in several ways:

- Multimodal Data Fusion: Integrating disparate sensor data using AI enables a richer understanding of process physics and defect formation.
- Predictive Microstructure Modeling: Combining machine learning with physical laws yields accurate, generalizable models of grain growth and phase evolution.
- Data-Driven Property Prediction: AI facilitates the discovery of complex P–S–P relationships that are otherwise intractable using traditional approaches.
- Closed-Loop Optimization: Embedding ML in real-time decision-making paves the way for fully autonomous, adaptive manufacturing systems.

The outcomes will significantly improve the performance, consistency, and cost-effectiveness of AM-fabricated components, especially for critical applications in aerospace, biomedical implants, and energy systems. Moreover, the proposed AI framework will enable more sustainable production by reducing trial-and-error, energy use, and material waste.

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Candidates should provide detailed CV

Contacts

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