AI-Enabled Multimodal Learning and Decision Making for Robotic 3D Concrete Printing

Linking Process Pre-Planning with In-Line and Post-Process Data Collection to Construct

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Introduction

In the coming decades, billions of people will need new housing and infrastructure, with reinforced concrete remaining central to meeting that demand. Yet conventional concrete construction is **expensive, labor-intensive, and material-intensive.**

Robotic 3D concrete printing (3DCP) can automate construction and reduce material use, particularly for materially efficient concrete structures (MECS). However, the key barrier is reliability: complex geometries are sensitive to time-dependent material behavior across a distributed fabrication chain (mixing, pumping, extrusion, and robot motion).

In practice, 3DCP remains **largely trial-and-error**, relying on manual observation and ad hoc tuning. This project replaces that approach with measurable, predictive relationships.

Research Objective

The research objective is to replace trial-and-error with **measurable, predictive relationships** that link:

- **Process planning — parameter selection and scheduling**
- **Time-dependent material response — rheology and curing**
- **As-built construct — geometric fidelity and structural outcome**

This enables decisions before printing (parameter selection) and during printing (anomaly detection/prediction and preventive intervention).

Artificial Intelligence (AI) is central to this project because the goal is to analyze and rationalize **heterogeneous, time-synchronized signals** from multiple sensors, deriving **actionable process–material–construct relationships** at construction scale that are complex for manual analysis.

Innovation & Impact

The innovation is treating 3DCP reliability as a multimodal problem in which time-dependent material behavior is latent and fab systems are decentralized.

- **Construct-level perception — geometry extraction from depth/point-cloud data combined with temporal models**
- **Temporal learning — from process signals and construct monitoring data**
- **Prescriptive decision making — linking learned relationships to planning and control actions**

The expected impact is improved geometric fidelity, repeatability, and reliability for 3DCP of MECS, with fewer failed prints and fewer trial-and-error iterations.