MSc Thesis - AI for 3D Concrete Printing

Requirements: programming, fundamental AI concepts and implementation, practical knowledge of deep learning, and interest in 3d printing.

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Project Description

Designing 3D printable materials has been, so far, a trial-and-error process dependent on human knowledge and effort; hence time-consuming and wasteful. To predict certain properties of 3DCP, material scientists have used modelling and simulations for decades. While helpful in many ways, models mostly require unrealistic assumptions and approximations. These challenges extend to the printing system too. As a result, the printing system is not optimized, causing frequent pauses to correct parameters; an example would be slowing down the printing due to low build-up rate of the material.

An alternative approach in 3DCP would be data-driven and AI-enabled, where historical as well as real-time printing data can be utilized in powerful AI models to improve the 3DCP systems. While AI has had huge success in domains ranging from autonomous driving and protein structure prediction to smart software development assistants, it has limited penetration into 3DCP so far, e.g. off-line prediction of certain material properties, compositions, printer settings and their correlations. An extensive in-line measurement of vast types and volumes of data during the whole 3DCP process, when fed into state-of-the-art machine learning models (e.g., deep learning), is entirely unexplored in the literature and has the potential to help discover new compositions, optimize 3DCP with real-time corrective action and autonomous operation.

Our printers already incorporate sensors for quantifying viscosity, pressure, and water content, as well as in-line measurement for the printed product (shape, colour, and temperature). The challenge is to utilize this data and find suitable AI techniques for advancing the state-of-the-art in smart 3DCP.

Objectives

1. Utilize (e.g. filter, cleanse, transform) high-quality and quantity measurement data from our printers regarding the whole 3DCP process;
2. Investigate the suitability of state-of-the-art and -practice generative AI for 3DCP, such as (a) finding hidden correlations among material properties and predicting final qualities such as printability for various compositions, and (b) controlling printer operation by executing corrective actions in real-time, e.g., changing the composition, mixing parameters and printing speed;
3. Train the AI models with the high-quality data collected in-site and report on their effectiveness;
4. [Optional] Deploy the AI models in our setup at TU/e and evaluate their effectiveness in real printing runs.

Literature

- Leonard Tudorache, Digital Twin for 3D Concrete Printing, Master Thesis, 22 Mar 2023, https://research.tue.nl/en/studentTheses/digital-twin-for-3d-concrete-printing
- Sergis, V., & Ouellet-Plamondon, C. (2023). An Optimum Mix Design Method for 3D Concrete Printing Applications. RILEM Bookseries, 44, 665–672. https://doi.org/10.1007/978-3-031-33187-9_61
- Yao, X., Lyu, X., Sun, J., Wang, B., Wang, Y., Yang, M., Wei, Y., Elchalakani, M., Li, D., & Wang, X. (2023). AI-based performance prediction for 3D-printed concrete considering anisotropy and steam curing condition. Construction and Building Materials, 375, 130898. https://doi.org/10.1016/J.CONBUILDMAT.2023.130898