Additive Manufacturing in Construction
2nd funding period: The Opportunity for Large Impact

AMC TRR277

B04

Process Control and Adaptive Path Planning for Additive Manufacturing Processes Based on Industrial Robots with an Extended Degree of Freedom

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Project aims of 2nd funding period

Enabling additive manufacturing with mobile robots during motion “print-while-driving”

- **Printing trajectory planning** for autonomous mobile robot systems (AMRs)
- **Simulation capabilities** to include effects of material properties and building installation
- Localization and **holistic control** for reproducible manufacturing with near nozzle correction and system localization
- **Surrogate modelling** for increased speed to allow for online stability prediction

Fig. 1: AMR with on board foam system for algorithmic development and testing

Work programme

WP 1 Extended planning

WP 1.1 Trajectory planning for mobile robot manufacturing

WP 1.2 Robot localization based on map prediction by process simulation

A04 B05

WP 2 Extended simulation

WP 2 Build-up simulation for multi-material and function integrated components

B06 A04 A03

WP 4 Surrogate modelling

WP 4.1 Requirements for surrogate modelling

WP 4.2 Developing deep learning models

WP 4.3 Evaluation and refinement

WP 4.4 Surrogate integration into trajectory planning

WP 3 Holistic control

WP 3.1 Substitute process design for trajectory and process control investigations — C09

WP 3.2 Object including process control strategies — A05

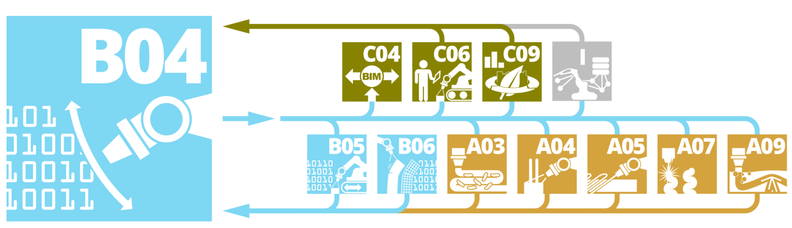
WP 3.3 Control of material properties — A04

WP 3.4 Mobile system control for print-while-driving — B05

WP 3.5 Manufacturing on existing structures based on print trajectory adaptation — C06

WP 3.6 On-site control concepts — B05

Key collaborations in 2nd funding period



- B04 provides mobile robot manufacturing algorithms to B05
- B04 provides knowledge in terms of material simulation to B06
- B04 assists A03, A04 and A05 in terms of process and material control
- B04 delivers process data to C06 for data based machine learning
- C09 will assist in development of a substitute printing process

Methods

Extended planning

- Transfer paths into trajectories
- Adding material properties as trajectory parameters
- Add objects such as rebar to the planning environment for control value prediction

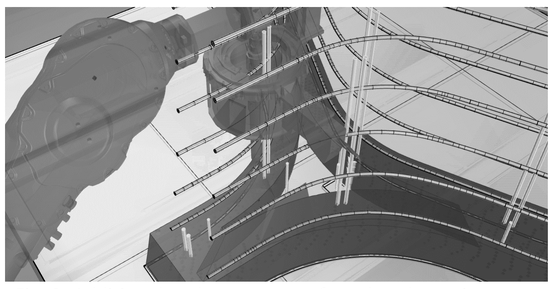


Fig. 2: Additional path parameters for robot dynamics, multi-material printing, and object integration such as rebar

- Generate multi-layer maps for online map exchange according to the build-status
- Adding collision avoidance by using occupancy maps

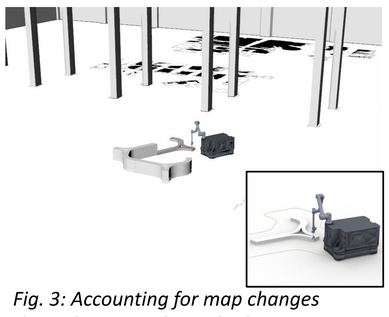


Fig. 3: Accounting for map changes through printing by multiple maps

Extended simulation

- Integration of visco-plastic material behaviour (from B06)
- Enable the simulation of graded concrete materials
- Integration of additional effects occurring through object placing

Fig. 4: Stability influenced by objects, Source: sbahnbau.bfx.de

Holistic control

- Vision based identification of building installation and rebar during printing

Fig. 5: The strand control is influenced by rebar. In-process image evaluation allows for object classification.

- On-board localization in combination with near nozzle compensation for accuracy

Fig. 6: Contour following to enable print-while driving

Surrogate modelling

- Investigation of sampling and data augmentation strategies
- Utilizing Deep Learning (e.g. NN) in combination with model reduction (e.g. Proper Orthogonal Decomposition)
- Linking surrogate with online path planning

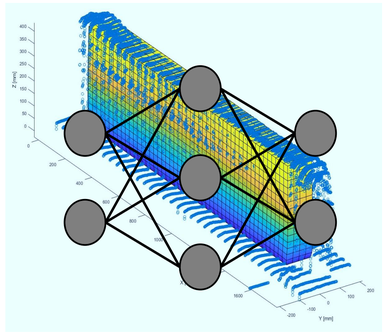


Fig. 7: Physics-based surrogate by Neural Networks for path planning

Outlook 3rd funding period

Onsite mobile manufacturing challenges

- Localization in **varying environments**
- Continuous nozzle motion with on-board sensing
- **Outdoor** environmental influences
- Onsite **floor conditions**

Fig. 8: On-site floor conditions, Source: BAUBOT

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