Robotic fabrication beyond factory settings

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Abstract

Significant effort in raising the degree of automation in building construction and architecture has been most successful in the area of off-site prefabrication. Smaller components of a building are made in a dedicated factory and subsequently transported to the building site for final assembly. Directly on construction sites, however, the level of automation is still comparably low. The final assembly of building components is heavily dominated by manual labor as opposed to other production industries, e.g. the automotive sector. It is then this very final step in construction which breaks the digital process chain between design and making.

What if - instead of building factories to fabricate building components - we begin seeing the construction site itself as the arena, within which the whole building is constructed by digitally controlled machinery at the spot? What possibilities would open up with the implementation of robotized in situ fabrication processes as opposed to digital fabrication in prefabrication? Can we utilize in situ digital fabrication to lower the expense for transport and energy by using local, ad-hoc available materials? And can we eventually redefine conventional construction processes, augment them with the use of robots and develop alternative tectonics to foster a sustainable use of resources, to minimize material waste and increase work safety on construction sites.

In order to find answers to these questions, Gramazio Kohler Research is investigating into these realms on the base of a variety of case studies, tackling the problem from different perspectives. Common to all is the notion to not only advance the efficiency of construction processes, but also the performance and aesthetics of the structures being built: after all, to find form generation and rationalisation to be directly influenced by the logic of making, whether this is concerning the choice of material and assembly systems or the specific features of a certain type of robot or robotic manipulation process. As such, three projects are described in the following which demonstrate indicative steps towards enabling the robotic construction of complex structures beyond factory conditions.

Keywords

Robotic fabrications; automation; digitally controlled machinery

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1 Remote Material Deposition

Remote Material Deposition follows the simple idea to expand the predefined workspace of a fixed base robot through the digitally controlled throwing of material to a remote location. Its formal expression results of its unique material morphologies as a direct expression of a dynamic and adaptive fabrication process, mapping out a new architectural landscape of 'Digital Materiality'[1].

2 Rock Print

Rock Print investigates on the principle of 'jamming', which refers to aggregate granular materials crammed together in such a way that it holds its form and shape like a solid. The project investigates and develops methods and techniques for the design and robotic aggregation of low-grade building material into load-bearing architectural structures. Due to the nature of the aggregation process, the structures have to be fabricated at the spot, but remain reusable and reconfigurable, and therefore offer a high geometrical flexibility with minimal material waste[2].

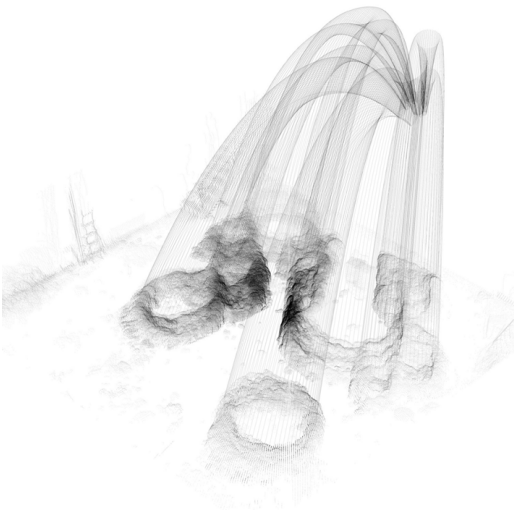

FIGURE 1 Ballistic trajectories of light projectiles through bulb exposure. © Gramazio Kohler Research
The implementation of 3D scanning during the build up process allowed to establish a feedback-loop on a geometrical level and therefore to intervene directly in the materialization process. © Gramazio Kohler Research

1 Dörfler, K., Ernst, S., Piskorec L., Willmann J., Helm, V., Gramazio, F., Kohler, M.: Remote Material Deposition: Exploration of Reciprocal Digital and Material Computational Capacities. In: What's the Matter: Materiality and Materialism at the Age of Computation, ed. Maria Voyatzaki, 361–77. Barcelona (2014)

2 Aejmelaeus-Lindström, P., Willmann, J., Tibbits, S., Gramazio, F., Kohler, M: Jammed architectural structures: towards large-scale reversible construction. In: Granular Matter.(2016)

3 In situ Fabricator

The development of the mobile robotic research platform - the In situ Fabricator - demonstrates a significant step towards enabling the automated material deposition and assembly processes beyond factory settings, but rather in an unstructured and ever changing environment such as a construction site. The mobility of the robotic machinery allows to build structures significantly larger than itself, and its location awareness and awareness of its surroundings allow for maximal flexibility and adaptability during a build up process[3] .

FIGURE 2 Rock Print - a jammed architectural structure consisting of gravel and string towering a mass of 1.2 x 1.5 x 6 m, demonstrated in 2015 at the Chicago Architecture Biennial. © Gramazio Kohler Research and Self-Assembly Lab, MIT
The structure was fabricated out of 10 m^3 of aggregates and 8 km of tensile reinforcement. © Gramazio Kohler Research and Self-Assembly Lab, MIT

FIGURE 3 The robots arm is equipped with a laser range finder. As the robot sweeps its arm, the laser measures points in space to generate a 3D map of its surroundings. This map is registered against an initial scan of the context in order to calculate the robot's position. (© NCCR Digital Fabrication)

3 Dörfler, K., Sandy, T., Giftthaler, M., Gramazio, F., Kohler, M., Buchli, J.: Mobile Robotic Brickwork - Automation of a Discrete Robotic Fabrication Process Using an Autonomous Mobile Robot. In: Robotic Fabrication in Architecture, Art and Design, pp. 205–217 (2016) and Helm, V., Ercan, S., Gramazio, F., Kohler, M.: Mobile robotic fabrication on construction sites: Dim-rob. In: 2012 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS) (2012)

Rerefences

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