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Design to Robotic Production for Informed Materialization Processes

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Abstract

Design to Robotic Production (D2RP) establishes links between digital design and production in order to achieve informed materialization at architectural scale. D2RP research is being discussed under the computation, automation and materialization themes, by reference to customizable digital design means, robotic fabrication setups and informed materialization strategies implemented by the Robotic Building group at Hyperbody, TU Delft.

Keywords

Robotic Production; automation; Scalable Porosity; informed materialization

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FIGURE 1 Recursive milling method: left - with homogenous resolution; middle - tool path with informed resolution based on material removal; right - prototyping.

1 Computation and design

Computation in architecture generates and processes large amounts of data resulting from algorithmic models involving multiple levels of resolution and scale. Inherently, computational design methodologies use analytical and generative routines that inform 3D models, often resulting in multidimensional arrays of associative spatial-material data. These require building logical relations between *information* and *matter* for the creation of inhabitable and efficient environments, with distinct materialization and aesthetics.

Specifically, the role of computation in robotic production systems is extended firstly, by the way machines are programmed and secondly, by the way material is distributed and behaviors are processed. The computation of the production logic applies procedural design that leads to synthetic forms of representation. For instance, *recursive milling* (figure 1) consists of continuous robotic paths with embedded information about form, material texture and fabrication constraints. Optimization of the path is embodied into a self-avoiding curve[1] that translates into a minimum length tool-path, featuring low and high resolution, for fast and slow material removal.

Another application of computation in robotic production has been explored through *porosity*. This implies quantifiable relations between matter and void that construct a computable binary system, in order to improve efficiency of building systems. Robotic path constraints are embedded as design drivers to create informed volumetric tectonics and surface textures (figure 2). Computation of porosity involves material optimization in order to facilitate optimal structural and environmental performance with minimal material use.

In this context, computation becomes more than series of logical steps for rationalization or performance optimization, but rather a part of design to production. This enhanced multi-dimensional computation model processes data related to material properties and robotic fabrication routines in order to address scalability of robotic fabrication.

1 Hilbert space-filling curve, first described by mathematician David Hilbert in 1891.

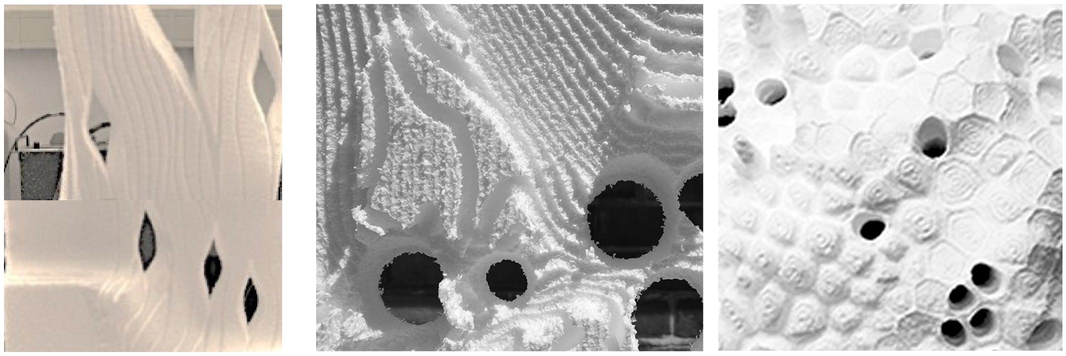

FIGURE 2 Materialization of informed porosity computed for volumetric tectonics and surface textures

2 Automation and robotic production

The integration of fabrication technology in architectural design promotes decentralized approaches in production processes and facilitates mass-customization. Open-source computation in design and production leads to the democratization of fabrication routines, effectively allowing both designers and users to access and operate industrial machinery on demand.

This has been explored at *InDeSem 2015* with a deployable setup (figure 3), which has been installed and became operational within a day. The production capacity of three industrial robots equipped with different tools allowed production of customized building components, the small programmable factory continuously operated 24/7 with design and fabrication data being shared between parametric models and robotic workstations.

The multi-technique robotic setup, focused on optimizing production workflow for subtractive fabrication and additive fabrication. It combined two subtractive fabrication techniques for prototyping, volumetric cutting for fast material removal and robotic milling to add further details and porosity. The efficiency of this multi-mode robotic fabrication approach resulted in the extension of both design space and production space. While all these applications used robotic motion as a tool for interacting with both digital and physical environments, the research aimed at integrating robotic technology into architectural design in order to achieve automation of building processes.

FIGURE 3 InDeSem: Deployable setup of three robots using several fabrication techniques (wire cutting, milling and drawing)

FIGURE 4 Scalable Porosity: Customised robotic set-up for 3D printing on ruled surfaces

With focus on Additive Manufacturing, another example of technology integration for automation of building processes, is the *Scalable Porosity* project (figure 4). The aim was to use robotically fabricated polystyrene components with ruled surfaces[2] as substrate to expand pre-existing fabrication capacity of ceramic clay, on curved surfaces. This research and operation implementation benefited from the clay extruder system[3] developed as part of the project. The numerically controlled plunger-based system for additive manufacturing employed small-medium range of robotic arms, with low payload but high precision, and effective speed for architectural scale.

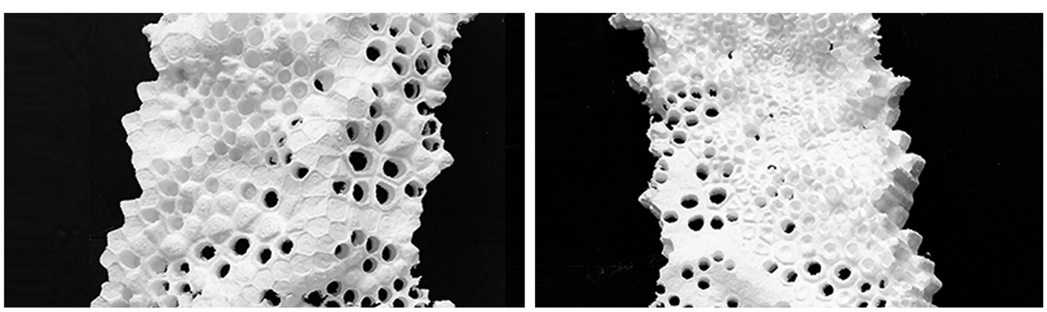

FIGURE 5 Porous Assembly: Exterior (left) and interior (right) sides

2 Pottmann, H., Asperl, A., Hofer, M. and Kilian, A. (2007). Ruled Surfaces, in Architectural Geometry. Exton: Bentley University Press, p.312.

3 Mostafavi, S., Bier, H., Bodea, S. and Anton, A. (2015). Informed Design to Robotic Production Systems. in eCAADe 2015 Volume 2 Real Time. Vienna: eCAADe, p.294.

3 Informed Materialization

In the presented case studies, informed materialization relies on multiple robotic production methods and materials in order to achieve quantifiable design performances. This has been reached through computational design and robotic materialization of porosity, hybridity and assembly at multiple scales ranging from macro-architectural and meso-componential to micro-material levels. As interface between digital design space and physical fabrication, materiality is mainly defined along three performance criteria: spatial functionality, structural capacity and environmental efficiency.

For instance, the *Porous Assembly* project implied differentiation in material thickness and variation in porosity, while considering multiple structural and environmental parameters (figure 5). The material was robotically approached from multiple directions, the strategy for robotic path generation being that of removing material where not needed. This project introduced a three-dimensional finger joint system, only producible through robotic fabrication, for the assembly of the mass customized components.

Hybrid Assembly (figure 6) focused on multi-materiality. Materials are distributed following properties and behaviors based on multiple design objectives. The project introduces one material namely cork to improve environmental acoustic performance of the building envelope. The three-dimensional intertwining of cork with structural polystyrene components creates a hybrid material system. The flexibility of the cork component is achieved through carving material from multiple directions with multiple resolutions.

4 Conclusion

By integrating computation, automation and materialization D2RP introduces strategies for extending and associating design space, fabrication space and material property space. Design space is enhanced by computation implemented at multiple scales, and fabrication relies on multimode robotic setups enhanced by several fabrication techniques, while materialization fuses porosity, hybridity and assembly for the production of informed architectural components and large-scale building assemblages

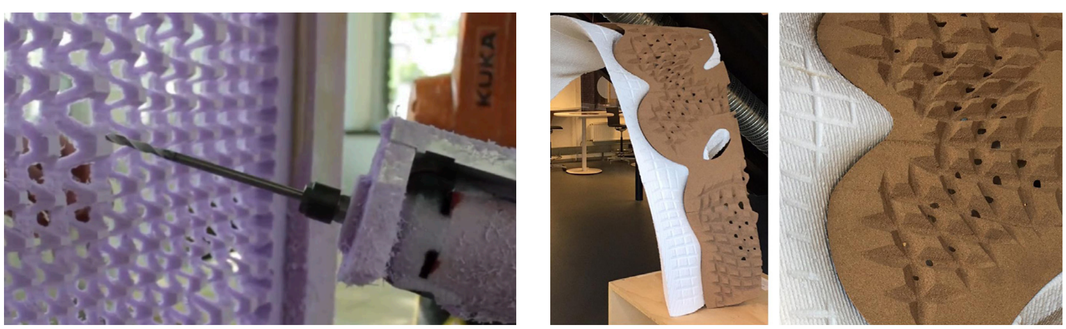

FIGURE 6 Hybrid Assembly, extending material properties to enhance the performance through integration of multiple materials and fabrication methods

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