Robotic Building as Integration of Design-to-Robotic-Production & Operation

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Abstract

Robotic Building (RB) implies both physically built robotic environments and robotically supported building processes. Physically built robotic environments consist of reconfigurable, adaptive systems incorporating sensor-actuator mechanisms that enable buildings to interact with their users and surroundings in real-time. These require design-to-production and operation chains that may be (partially or completely) robotically driven.

Keywords

Robotic environments; Robotic Building; Design-to-Robotic-Production; Design-to-Robotic-Operation.

1 Introduction

While architecture and architectural production are increasingly incorporating aspects of non-human agency employing data, information, and knowledge contained within the (worldwide) network connecting electronic devices, the relevant question for the future is not whether robotic building will be implemented, but **how robotic systems will be incorporated into building processes and physically built environments**[1] in order to serve and improve everyday life.

This 1st issue of SPOOL in 2007 aims to answer this question by critically reflecting on the achievements of the last decades in applications of robotics in architecture and furthermore outlining potential future developments and their societal implications. The focus is on robotic systems embedded in buildings and building processes implying that architecture is enabled to interact with its users and surroundings in real-time and corresponding design-to-production and -operation (D2P&O) chains are (in part or as whole) robotically driven. Such modes of production and operation involve agency of both humans and non-humans. Thus agency is not located in one or another but in the heterogeneous associations between them[2] and authorship is neither human or non-human but collective, hybrid, and diffuse.

2 Robotic Building

Robotic Building (RB) relies on interactions between human and non-human agents not only at design and production level but also at building operation level, wherein users and environmental conditions contribute to the emergence of multiple architectural configurations. RB implies both physically built robotic environments (fig.1) and robotically supported building processes (fig.2&3). Physically built robotic environments consist of reconfigurable, adaptive systems incorporating sensor-actuator mechanisms that enable buildings to interact with their users and surroundings in real-time. These require **design-to-production (D2P) and operation chains that may be (partially or completely) robotically driven**.

In this context, design becomes process- instead of object-oriented, use of space becomes time- instead of program- or function-based, which implies that architects design increasingly processes, while users operate multiple time-based architectural configurations[3] emerging from the same physical space that may physically or sensorially reconfigure in accordance to environmental and user specific needs.

1 Bier, H. (2013) 'Robotic(s in) Architecture', Interactive Architecture #5 (Heijningen: Jap Sam Books), pp. 6-8

2 Latour, B. (2014) Reassembling the Social: An Introduction to Actor-Network-Theory (Oxford: Oxford University Press), pp. 63-86

3 Bier, H. and Knight, T. (2010) 'Digitally-driven Architecture', Footprint #6 (Delft: Stichting Footprint), pp. 1-4

FIGURE 1 Design-to-Robotic-Operation framework developed at TUD (2013-16)

In this context, spatial reconfiguration may be facilitating multiple, changing uses of physically built space within reduced timeframes. Furthermore, interactive energy and climate control systems embedded in building components and employing renewable energy sources, such as solar and wind power, may reduce architecture's ecological footprint while enabling a time-based, demand-driven use of space[4]. Both rely on virtual modelling and simulation that interface the production and real-time operation of physically built space[5] establishing thereby an unprecedented design-to-robotic-production and -operation (D2RP&O) feedback loop, which is focus of this issue.

NGB #3 presents extended abstracts from the RB session hold 2016 at the GSM#3 symposium. Most abstracts discuss D2RP&O as separate and quite different processes, while RB aims at the integration of two.

4 Liu Cheng, A. and Bier, H. (2016) 'An Extended Ambient Intelligence Implementation for Enhanced Human-Space Interaction', Proceedings of the 33rd International Symposium on Automation and Robotics in Construction, pp. 778-786

5 Bier, H. and Knight, T. (2014) 'Data-driven design to production and operation', Footprint #15 (Delft: Stichting Footprint), pp.1-5

3 D2RP

D2RP is discussed by Kathrin Dörfler in terms of robotic fabrication implemented directly on construction sites. She brings robots directly to the construction site (video 1) in order to autonomously fabricate structures outside factories. Jelle Feringa explores the industrial ramifications of architectural robotics (video 2), while Justin Dirrenberger implements with XtreeE robotic 3D printing with concrete on and off site. He also introduces architectured materials bridging across the micro-scale of materials and the macro-scale of engineering structures. He identifies this as a paradigm shift. According to him, materials cannot be considered monolithic anymore as any set of materials functions, even antagonistic ones, can be envisaged in the future.

4 D2RO

D2RO is discussed by Sebastian Vehlken by critically examining the techno-history of robotics, which intertwines engineering and biological knowledge and whose applications deal with questions about self-organization in changing environments – on the ground, in the air, and under water. Keith Evan Green investigates interactive, intelligent, and adaptable environments (video 3) by way of embedded robotics. He examines how architectural robotic systems support and augment everyday life at work, school, and home, while Holger Schnädelbach is concerned with buildings that are specifically designed to adapt to their environment and to their inhabitants. His focus is on how architects and inhabitants co-create Adaptive Architecture, how the emerging feedback loops shape people's behaviours and how inhabitants and environment become interaction partners.

5 D2RP&O

The integration of D2RP with D2RO implies understanding both approaches as requiring safe human-robot interaction and collaboration in the production and operation of buildings. Since production and operation of buildings takes place in more or less unstructured environments both imply similar challenges and opportunities.

Integrated D2RP&O as explored at TUD, addresses the notion of hybrid componentiality, where the components of a system are designed to embody a *hybrid* whole. In this context, the D2RP is informed by structural, functional, environmental, and assembly considerations[6]. At the micro-scale, the material is conceived as a porous system, where the degree and distribution of porosity i.e. density are informed by functional, structural and environmental requirements, while taking into consideration both passive (structural strength, thermal insulation, etc.) and active behaviours (adaptive, reconfigurable, etc.). At the meso-scale, the component is informed mainly by the assembly logic, while at the macro scale, the assembly is informed by architectural considerations[6].

6 Mostafavi, S. and Bier, H. (2016) 'Materially Informed Design to Robotic Production: A Robotic 3D Printing System for Informed Material Deposition', Robotic Fabrication in Architecture, Art and Design 2016 (International: Springer), pp. 338-349

By integrating sensor-actuators such as light dependent resistors, infrared distance sensors, pressure and accelerometer sensors, etc. that are informing lights, speakers, heaters, ventilators, and/or reconfigurable building components, users implicitly and explicitly customize the use of the physically built space.
For D2RO, a distributed and decentralized system architecture is employed to identify activities4 in order to engage users proactively and to enhance their experience.

The ambition is to advance D2RP&O methods in order to increase process- and material-efficiency and improve interactive use of physically built space. RB is unique in its aim to link design and production with smart operation of the built environment and advances applications in performance optimization, robotic manufacturing, and user-driven operation in architecture.

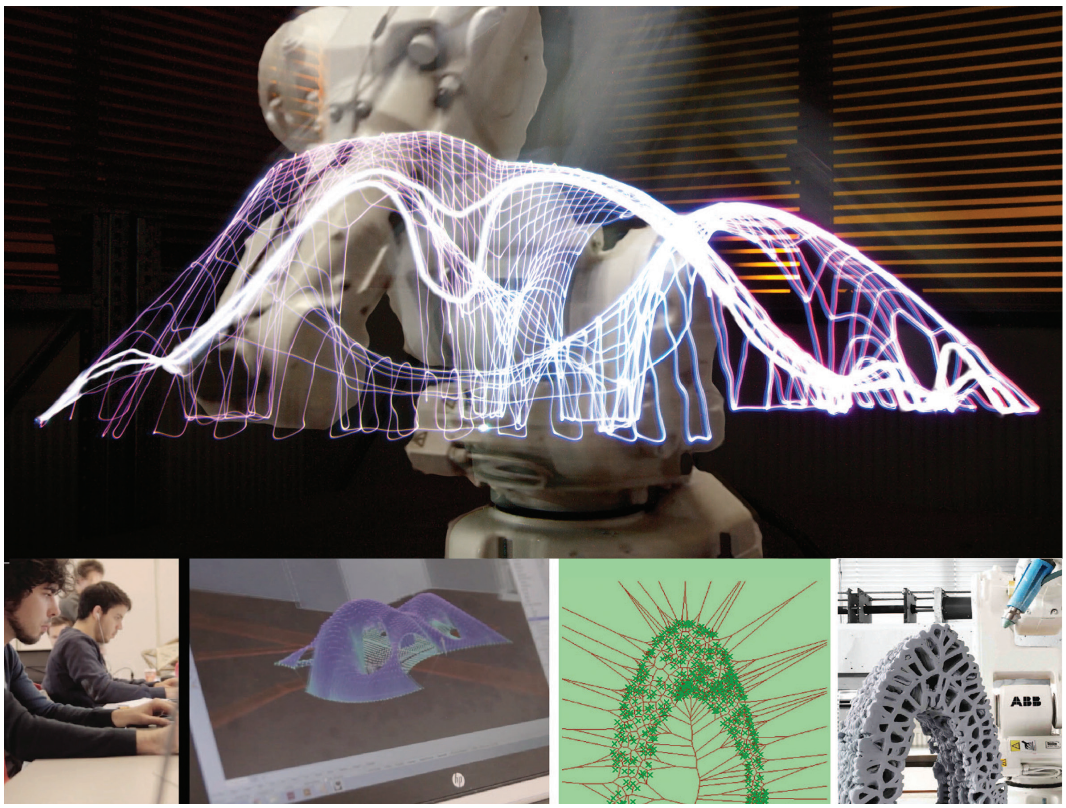

FIGURE 2 Design-to-Robotic-Production developed at TUD (2014-16)

Acknowledgements

This paper has profited from the contribution of Hyperbody and in particular Robotic Building researchers and MSc students involved in the presented projects. It furthermore, profited from the presentations and discussions during the Robotic Building session at the Game Set Match #3 symposium organised at TUD, 2016.

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