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LETTER FROM THE EDITOR

Geometry to Fabrication in Architecture

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Abstract
This letter from the guest editors introduces Vol. 25(4) of the *Nexus Network Journal: Architecture and Mathematics*. In this special issue, 11 research contributions examine the influence of geometry on the process of making in architecture and vice versa. From fabrication experiments with industrial robots and investigations of geometry and material constraints to the development of the theoretical framework of shape rules and making grammars, the contributions in this issue present the research potential that translates architectural geometry into physical objects in architecture.

Keywords Architecture · Mathematics · Geometry · Fabrication

Introduction

The geometry of complex shapes has always played an important role in architectural design and the process of building construction. From the first vaults to the later stereotomic shells and now to digitally fabricated architecture, understanding the logic of geometry in the process of construction and fabrication has been crucial. Recent developments in computational design tools enable easier creation of complex shapes that might be challenging for manufacturing and hence further emphasizes the importance of the relationship between geometry and fabrication in the design process.

Digital technology has influenced the development of a new way of design thinking that seamlessly integrates construction, fabrication, and material constraints into the language of shapes and architectural geometry. Novel design methods, such as fabrication-aware design, structurally informed design, and material-based

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design, reflect an increased interest in creating new relationships between geometry and fabrication in architecture. The main intention of these emerging design approaches is to explore and develop innovative ways to align geometric principles with the intricacies of the fabrication process, thereby pushing the boundaries of architectural design. These approaches signify a heightened focus on establishing new relationships between geometry and fabrication within the field. The objective of this special issue is to examine different relationships between geometry and fabrication in architecture.

Vol. 25(4) of the *Nexus Network Journal: Architecture and Mathematics* presents various approaches to the influence of geometry on the process of making and vice versa. From fabrication experiments with industrial robots and investigations of geometry and material constraints to the development of the theoretical framework of shape rules and making grammars, the contributions in this issue present the research potential that translates architectural geometry into physical objects in architecture.

Geometry to Fabrication

This issue starts with two papers that investigate the relationship between geometry, the design process and robotic fabrication. The issue opens with 'Form-Finding to Fabrication: A Parametric Shell Structure Fabricated Using an Industrial Robotic Arm with a Hot-Wire End-Effector'. In this paper Jin-Ho Park and Sejung Jung experiment with form-finding and robotic fabrication to explore innovative design possibilities for shell structures while evaluating and maintaining fabrication constraints and the constructability of the designed form. The fabricated structure demonstrates that Park's and Sejung's approach complements the potential impacts of the design process, practice, and aesthetics. In the next paper investigating robotics in architecture, entitled 'Fabricating Porous Structures Using Robotic Hotwire Cutting' Marko Vučić, Marko Jovanović and Mirko Raković examine the concept of porosity and fabrication challenges arising from the complex topology of porous structures. They propose a novel design and manufacturing approach for porous structure fabrication that uses a hot knife tool with an industrial robot to cut expanded polystyrene materials.

As with the previous, the following two papers investigate the relationship between geometrical patterns and fabrication methods. In 'Application of Fabric Formwork based on a Truchet Tiling Pattern for Planar Surfaces', Felicia Wagiri, Shen-Guan Shih, Kevin Harsono and Jia-Yang Lin investigate how flexible membranes, such as polyester, can create natural tension shapes that rigid molds cannot achieve. The authors propose a hybrid design technique for precast panels that incorporates soft-material formwork, computational form-finding, and the Truchet tiling concept. As a result, they develop a computational framework and fabrication method for fabric formwork that will allow new architectural forms in precast panels. In the next paper 'Surface Patterns in Architecture Driven by Image Sampling and Robotic Fabrication' Bojan Tepavčević, Vesna Stojaković, Marko Jovanović and Mirko Raković investigate different strategies for creating

surface patterns based on image sampling and using industrial robots as fabrication tools. The authors present three different design-to-fabrication methods in order to achieve three different wall surface treatments with intriguing geometric and optical properties based on image sampling. The presented experimental tests demonstrate that the interplay between parametric design, material properties, fabrication tools, and assembly is conducive to the creation of an abstract image that possesses shape constancy related to the visual perception of an image.

The next two papers present experiments that combine geometry, material, and fabrication constraints. In 'Parametric Interlocking Elastic Wooden Plate Joint for Complex Structures' Isbah Estateyieh and Semra Arslan Selcuk develop an elastic wood joint for the complex geometries of plate components using parametric modelling. They investigate the fabrication of a physical prototype from wood to test the applicability of the developed elastic joint. The result leads to the development of digital and physical prototypes of a wooden shell pavilion with a parametric interlocking elastic wooden plate joint. In 'Learning from Folding Paper to Develop Folding Mechanisms' Özlem Çavuş and Arzu Gönenç Sorguç propose a method for designers to develop kinetic structures derived from folding patterns. They investigate how these folding patterns can be used to generate mechanisms free of common problems like self-locking. The study also examines geometric formations of kinetic surfaces regarding seventeen symmetry groups of crystals to understand global motion and its enablers. The research is validated through a case study showing how an arbitrary sketch is transformed into an actual kinetic structure by folding a paper model, digital simulation, and a prototype.

The next three papers incorporate the theory of shape grammar, the design process, and the making process. In the first of these, 'Rule-based Milling of Medieval Stone Patterns', Begum Hamzaoglu and Mine Özkar develop a set of detailed making rules and a parametric model with the consequent toolpaths for 3-Axis milling for a specific style of relief ornaments. Such rule sets can be developed for the reconstruction of historical stone ornaments commonly used in Seljuk architecture. The authors' unique method demonstrates the making of stone carving patterns with a holistic approach based on the relationships of successive material shape formations with milling tools and actions. In 'Designing the Ice-Crack Pattern of Traditional Chinese Windows' Zhen Zhang examines a decorative scheme in traditional Chinese window design ('ice-crack pattern') on the window cases by conducting geometrical, proportional, and statistical analysis and considering the structural integrity of the wood structure. This study reveals a design process that starts with 'key figure(s)' and expands towards the periphery of the windows, complementing the design theorist George Stiny's work and revealing the form-generating rules in ice-crack patterns. In 'A Mathematical Formalization of Making Grammars' Ayodh Vasant Kamath makes a contribution to design theory by establishing a mathematical framework that elucidates the relationship between shape grammars and making grammars. By establishing this connection, Kamath enables the extension of advancements made in shape grammar theory into the material realm through the utilization of making grammars.

This special issue also features two papers that explore architectural fabrication and geometry as a didactic method.

In 'Integrating Robotic Fabrication into the Basic Design Studio', Tuğrul Yazar, Hülya Oral-Karakoç and Gamze Gündüz reveal the educational potential and strategies of robotic arms as design and production tools. The authors present an experiment that took place in a first-year design studio at a faculty of architecture in order to explore ways to implement robotic fabrication as a continuation of the hands-on making process. Due to the fact that first-year architecture students have insufficient technical knowledge in the fabrication process, the authors aim to investigate how students' design intentions influence the development of their technical expertise and, conversely, how the acquisition of technical knowledge shapes and refines their design intent.

In another didactics paper 'Experimental Structural Model: From Manual Paper Garment to Fabrication as an Architectural Practice-Based Approach for Fashion Design Education' Deena El-Mahdy presents a study of architectural design approaches in the fashion design process, suggesting a new educational method based on structural model fabrication. The paper addresses the output of an experimental collaborative practice-based workshop that involves both architects and fashion designers. The resulting garments demonstrate that folding techniques can be used to achieve stability and highlight the interdisciplinary integration of architects and fashion designers. The study concludes that implementing a parametric design logic based on an architectural perspective in fashion would generate innovative ways of testing self-supporting geometry.

We aspire for this special issue of the *Nexus Network Journal* to serve as a catalyst for new research and in-depth reflections on the interplay between architectural geometry and fabrication. We wish to thank all contributors to this special issue, with a special thanks to Kim Williams and Michael J. Ostwald, Editor-in-Chief, for inviting us to be the guest Editors. Their dedication and unwavering commitment to excellence have transformed the NNJ into an exceptional publication and a remarkable community of scholars.

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