Editorial

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Craftsmanship has, throughout ages, played an important role in the making of artifacts, buildings and environments. In architectural research though, craft tends to be viewed as a domain of exploration which has not garnered respect on par with traditional areas of research. As robotics continues to penetrate deeper into the academic/professional realms of design and construction, we have witnessed a growing number of researchers who have reinvented architectural research through the lens of robotic craft. This issue of *Construction Robotics* will explore the research merits of craftsmanship through its direct link between design, novel materials, robotic systems and machine learning within the fields of architectural research, design and construction.

Over the past 15 years, advanced technologies such as computation, composite materials, robotics and machine learning have afforded designers, researchers and makers' the ability to reimagine how artifacts, systems, buildings and environments are designed, detailed, crafted and constructed. These changes are visible in research and practice over the past four decades in design and construction through a paradigm shift that led from hand drawing and production to CAD (Kemper 1985); digital design/modelling (Lynn and Kelly 1999); digital fabrication (Iwamoto 2013); computation modelling and CNC production (Leach and Yuan 2018); and most recently into the realms of machine learning, AI and robotic production (Daas and Wit 2018a).

In the early 2000's, digital fabrication redefined how designers made prototypes and built artifacts through the affordances made possible by the linking of design and making to computation and CNC based operations such as the milling, cutting, material processing or printing of various architectural materials (Cabrinha 2010). The direct linking of the design process back to making not only allowed for the creation of new types of forms, material systems and levels of precision during construction, but also allowed

designers to rethink architectural research in relationship to a new digital craftsmanship (i.e. digital craft) (Kolarevic and Duarte 2018). This new craft allowed for the exploration of the minutest details. From formal operations such as folding or tessellating to material operations such as texture, variable opacity or material hybridity. Although digital fabrication allowed for new research and typological outcomes in architecture, the scale of these artifacts tended to be limited by the lack of ability to customize a given tool or machine, reliance on standardized materials, fixed machines and/or infrastructure, high costs of tools, as well as the limitations associated with the file to fabrication production methodology.

Unlike the previous paradigm of digital fabrication, robotic production opens up a new subset of affordances for the crafting of built artifacts because of their inherent flexibility and adaptability (Daas and Wit 2018b). Whereas in digital fabrication, research was artifact centric, where a predetermined design was built around methods such as file to fabrication, tool specific operations/programming and the limitations a specific tool, robotic production allows for materials, tools, processes and adaptive/intelligent systems to be built for and around real-time making, unique/hybrid materials/material systems, textures, tasks and designs. This newfound ability empowers the designer/researcher to not only craft form, but also affords them with the ability to craft every digital and physical process, material and tool that leads up to the finished artifact which may or may not be the same as the initial design input.

Through the lens of craft, this issue of *Construction Robotics* explores the algorithms, machine learning tools, materials, processes and production tools that are being developed in the world's leading research institutions to reinvent craftsmanship in the fields of architecture and construction. Specifically, the articles featured explore the processes of crafting prototypes, structures, pavilions ranging from: multi-robot coordination and collaborations systems for the construction of structures built from novel composite materials to vision-guided approaches for material application allowing for non-human input throughout the production process; articles will investigate the software and material

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limits associated with the robotic metal 3D printing of architectural components; and finally, they will explore the utilization of robotic systems, 3D scanning, and computation as a means of utilizing atypical, heterogeneous materials in large-scale construction both in on and off-site applications.

The scope of this issue aims to bring forward the importance of craftsmanship in architecture, engineering and construction through the highlighting of groundbreaking research that is not only furthering robotics within the discipline or within industry, but also aiding in the redefining of the built environment. These contributions show that craft moves beyond the human and the artifacts created by hand, and in all actuality, touch upon all aspects of the design process, from software to end-effector. They also emphasize the importance of understanding where our current tools and methodologies have come from in the past, to better understand their future potential.

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