

Robotic Fabrication in Architecture,  
Art and Design 2014

Wes McGee · Monica Ponce de Leon  
Editors

# Robotic Fabrication in Architecture, Art and Design 2014

Foreword by Johannes Braumann and Sigrid Brell Cokcan,  
Association for Robots in Architecture

with contributions by Aaron Willette

 Springer

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# Foreword by the Association for Robots in Architecture

When the Association for Robots in Architecture was founded in 2010, just a few institutions in the world utilized robots in a “creative” context. While the works of pioneers such as Gramazio and Kohler were already widely published in architecture and design media, only a few selective clusters of creative robotic research existed, but no real network to foster collaboration and the exchange of ideas. Architects and designers considered robots to be machines that are capable of doing great things in the hands of engineers and researchers, rather than tools that can facilitate or even inform their own work in the near future. Thus, the purpose of the Association for Robots in Architecture was clear from the beginning; to “make industrial robots accessible to the creative industry”. We pursue that goal with two parallel strategies: On the one hand, by developing the software KUKA|prc for easy robot control within a CAD environment, and on the other hand by acting as a network and platform toward an open access to robotic research.

Following more than a year of preparation, the first conference on robotic fabrication in architecture, art, and design—RoblArch 2012—took place in December 2012 in Vienna. Initially conceptualized as a symposium with a few dozen participants, it quickly turned out that there was significant interest from both academia and industry. Eight internationally renowned institutions joined us by offering two-day robot workshops—instead of just talking about the results of robotic fabrication, the robot labs were opened to the public for the very first time, giving participants an insight into the processes and workflows that usually take place in closed research labs. Also the robot industry realized the potential of new, creative robotic applications, with KUKA acting as the main conference supporter, alongside the sponsors ABB, Stäubli, Schunk, Euchner, Zeman, and splineTEX. Finally, more than 250 people attended the conference, with around 100 of them actively participating in the robot workshops.

The effects of RoblArch 2012 can still be felt, in the form of collaborations, business deals, and also friendships. Still, within the 18 months that have passed between RoblArch 2012 and RoblArch 2014, the robotic landscape of the creative industry has grown—and changed—rapidly. Many universities have acquired both small and larger robots, building upon existing plugins for Grasshopper to rapidly introduce their students to programming complex machines. At the same time, an increasing number of artists, architects, and designers are starting to see robotic arms as valuable design tools, while innovative firms in the classic automation

business are observing the benefits of new, design-driven strategies for controlling robotic arms. This development is mirrored in the member-list of the Association for Robots in Architecture: While two thirds of the members are universities, the remaining third is made up by individual artists, fablabs, and offices, but also enterprises like Absolut and Boeing. Looking forward to RoblArch 2016, this ratio may approach 50/50.

RoblArch 2014, and this book, are representative of these changes, spanning the wide range from Google's Bot & Dolly, using robots in cinema, to highly technical robotic applications depending on sensor-based feedback in the contributions from industry partners KUKA, ABB, Stäubli, and Schunk. While in 2012 European institutions hosted universities from the United States, this year the University of Michigan and workshop co-host Carnegie Mellon University collaborate with partner-institutions from Germany, Australia, Spain, and Austria, while Princeton University is teaming up with a university spin-off, Greysheed.

Since the very beginning, the use of robotic arms has been a collaborative effort involving many "trans" disciplines. RoblArch 2014 again fosters the exchange of ideas not only between researchers, but also between all kinds of professionals, hackers, artists, and enthusiasts.

We want to thank the editors and conference chairs Wes McGee and Monica Ponce de Leon, as well as their entire team, for their hard work in making RoblArch 2014 happen. Furthermore, we want to congratulate all workshop institutions for sharing their ideas and workflows, which is most valuable for the whole community in regards to *open access* and a rapid knowledge transfer. Finally, we are grateful for the generous support of our industry partners, who do not only support the funding of the conference and the workshop infrastructure, but also devoted themselves to supporting young potentials and talents in this new field through the *KUKA Young Potential Award* and the *ABB Mobility Grant*.

We hope to see you all again at RoblArch 2016!

Sigrid Brell-Cokcan  
Johannes Braumann

# Preface

The work presented in this book exhibits the continuing evolution of robotic fabrication in architecture, art, and design. Once the domain of only a handful of institutions, the application of robotic technologies in these disciplines is consistently growing, led by interdisciplinary teams of designers, engineers, and fabricators around the world. Innovators in the creative disciplines are no longer limiting themselves to off-the-shelf technologies, but instead have become active participants in the development of novel production methods and design interfaces. Within this emerging field of creative robotics a growing number of research institutions and professional practices are leveraging robotic technologies to explore radical new approaches to design and making.

Over the last several decades there has been a widely discussed adoption of digitally driven tools by creative disciplines. With designers seeking to push the limits of what is possible using computational design, parametric modeling techniques, and real-time process feedback, industrial robotic tools have emerged as an ideal development platform. Thanks to advances by established manufacturing industries, the accuracy, flexibility, and reliability of industrial robots has increased dramatically over the last 30 years. The accessibility of the technology to new users has also increased dramatically, with many manufacturers adopting open standards for connectivity and programming. Designers have taken the flexible nature of industrial robotic technology as more than just an enabler of computationally derived formal complexity; instead they have leveraged it as an opportunity to reconsider the entire design-to-production chain.

This is not to say that industrial robots have become mainstream. As with all digital technologies that have entered into creative disciplines, the development of knowledge surrounding the use of robotic fabrication methodologies is ongoing. And while the productive impact of their possibilities and resistances on these disciplines remains an exciting and contested territory, they have had a palpable effect that is actively shaping contemporary discourse.

## Rob|Arch

Initiated by the Association for Robots in Architecture as a new conference series focusing on the use of robotic fabrication within a design-driven context, RoblArch—Robotic Fabrication in Architecture, Art and Design, provides an opportunity to foster a dialog between leading members of the industrial robotic industry and cutting-edge research institutions in architecture, design, and the arts. In December 2012, the first conference was hosted by its founders Sigrid Brell-Cokcan and Johannes Braumann in Vienna, Austria; now in its second iteration the 2014 conference travels to North America, hosted by the University of Michigan Taubman College of Architecture and Urban Planning. The Taubman College is well known as an academic institution for its diverse and multifaceted approach to design education, as well as its long-standing traditions in pursuing making as a form of knowledge creation.

One of the features of the RoblArch conference series is its focus on fabrication workshops, where leading research institutions and creative industry leaders host workshops lead by collaborative teams from around the globe. For the 2014 conference workshops there was an open call for proposals, with eight workshops selected to be held at the University of Michigan, Carnegie Mellon University, and Princeton University. Many of the workshops are based on cutting-edge work currently in progress, and their accompanying texts are published in the “Workshop Papers” section of the book.

The selected workshops cover a wide range of experimental robotic fabrication processes. The contribution from the Institute for Computational Design at University of Stuttgart focuses on their novel methodology for the production of wound composite components using cooperative robotic manipulators to produce variable units from reconfigurable tooling. A collaborative team from the University of Technology, Sydney and the University of Michigan is investigating robotic bending, cooperative assembly, and welding toward the production of complex architectural components. A workshop taught by a collaboration between the University of Michigan and IAAC focuses on sensing and material feedback within a cooperative robotics workcell. Bot & Dolly, one of the Industry Keynotes for 2014, will lead a workshop on procedural fabrication that showcases their innovative control software. Bot & Dolly is design and engineering studio that specializes in automation, robotics, and filmmaking. At Carnegie Mellon University’s dFab Lab one workshop will couple cooperative robotic steam bending with integrated sensing techniques, while a team from the University of Innsbruck and the Harvard GSD will lead a workshop utilizing cooperative manipulators for the development of novel building components using phase change polymers. A third workshop at CMU will be led by a team from the Harvard GSD and TU Graz on the sensor-informed fabrication of reformable materials. And last, but not least, Princeton University will host a workshop on augmented materiality, using real-time sensor feedback and custom hardware interfaces to explore the closed-loop fabrication of structurally-optimized components.

Reflecting on the workshop and scientific paper submissions a number of themes emerged that will define both this year's conference and the near-future of robotic fabrication research, many paralleling the state of robotics and automation in other manufacturing industries. Sensor-enabled processes and robotic vision are addressed in a number of papers, both as techniques for in-process tolerance gauging and as adaptive path-planning tools. From the exploration of sensor enabled on site construction techniques, to new techniques for digitally controlled metal forming, designers and architects are expanding the capabilities of the tools at their disposal. Additionally, research projects involving cooperative robots are becoming more common, as research labs around the world have invested in multirobot work cells. This can be viewed as an indication that robotic fabrication research in architecture and design is about much more than just the subtractive or additive techniques analogous to traditional CNC processes: researchers are actively developing production methods which represent entirely new paradigms for fabrication. This is not to suggest that novel work on additive, subtractive, and material forming processes is not occurring; on the contrary, a number of papers address these topics, at scales ranging from the size of a building component, to a mobile platform capable of reaching the scale of a building.

One aspect that has been critical to this adoption has been continued focus by researchers and designers to challenge the norms of standard industrial workflows and machine interfaces. Such research continues to be a key aspect of advancing the possibilities for robotic technology to empower the design process. What is significant, however, is that robotic tools are enabling designers and architects to develop processes that suit the material, scalar, and tectonic needs of their discipline. Robotic technologies provide the ideal platform for developing fabrication processes in an experimental, iterative framework, without reinventing the machines of production.

Perhaps the most exciting trend in the field has been the growing level of knowledge transfer occurring between researchers, designers, and industry partners. The integration of robotic technologies into the workflows of creative industries has demanded renewed levels of cross-disciplinary collaboration. To further this exchange, industry partners were invited to submit papers documenting recent projects in the context of their value to art, architecture, and design. Their submissions illustrate the diversity of research and development going on in the industry, from force-control and adaptive gripper applications demonstrated by Schunk, to lightweight robotic systems by KUKA, dedicated material removal robots by Stäubli, and linked kinematic handling with cooperative robots by ABB.

As new technologies are developed across a wide range of robotic industries, innovators in the creative disciplines will continue to adapt and transform these tools to suit their specific applications. This is more than simple technology transfer, however, as robotic technologies are having a visible impact on the discourse surrounding the means and methods of production in the creative industry. Around the world this discourse is shaping not only how designers look at fabrication technologies, but the entire methodology by which they engage design and material production. As creative industries continue to explore and



develop new applications for robotic technology, we look forward to new innovations enabled through collaboration between industry, academia, and the growing community of designers, programmers, and trendsetters surrounding “Robots in Architecture.”

The conference chairs would like to thank the CEO of the KUKA Robot Group, Stu Shepherd and Alois Buchstab of KUKA Roboter GmbH who devoted themselves to make this conference and scientific book possible, ABB for their main support of the workshops together with Stäubli and Schunk, as well as our advisory board, and the Association for Robotics in Architecture for the opportunity to organize the conference. In addition we would like to thank the Scientific Committee, composed of architects, engineers, designers, and robotic experts; without their help it would not have been possible to develop the quality of work presented within. Special thanks to our assistant editor, Aaron Willette, for his tireless support. An especially important thanks goes to the entire team at the Taubman College of Architecture and Urban Planning, including both staff and faculty, who have supported the development of the conference. We would also like to thank our peer institutions who graciously agreed to host workshops: Carnegie Mellon University and Princeton University. Finally, special thanks to Springer Engineering for their assistance in editing and publishing these proceedings.

Wes Mcgee  
Monica Ponce de Leon

# Contents

## Part I Scientific Papers

<b>Variable Carving Volume Casting</b> . . . . .	3
Brandon Clifford, Nazareth Ekmekjian, Patrick Little and Andrew Manto	
<b>Bandsawn Bands</b> . . . . .	17
Ryan Luke Johns and Nicholas Foley	
<b>An Investigation of Robotic Incremental Sheet Metal Forming as a Method for Prototyping Parametric Architectural Skins</b> . . . . .	33
Ammar Kalo and Michael Jake Newsum	
<b>An Approach to Automated Construction Using Adaptive Programing</b> . . . . .	51
Khaled Elashry and Ruairi Glynn	
<b>Design and Fabrication of Robot-Manufactured Joints for a Curved-Folded Thin-Shell Structure Made from CLT</b> . . . . .	67
Christopher Robeller, Seyed Sina Nabaei and Yves Weinand	
<b>Robotic Bead Rolling</b> . . . . .	83
Jared Friedman, Ahmed Hosny and Amanda Lee	
<b>A Compound Arm Approach to Digital Construction</b> . . . . .	99
Steven Keating, Nathan A. Spielberg, John Klein and Neri Oxman	
<b>Design of Robotic Fabricated High Rises</b> . . . . .	111
Michael Budig, Willi Viktor Lauer, Raffael Petrovic and Jason Lim	
<b>FreeFab</b> . . . . .	131
James B. Gardiner and Steven R. Janssen	

<b>Additive Manufacturing of Metallic Alloys</b> . . . . .	147
James Warton, Rajeev Dwivedi and Radovan Kovacevic	
<b>TriVoc</b> . . . . .	163
Dagmar Reinhardt, Densil Cabrera, Marjo Niemelä, Gabriele Ulacco and Alexander Jung	
<b>Performative Tectonics</b> . . . . .	181
Philip F. Yuan, Hao Meng and Pradeep Devadass	
 <b>Part II Projects</b>	
<b>Integrated Design and Robotized Prototyping of Abeille’s Vaults</b> . . . . .	199
Thibault Schwartz and Lucia Mondardini	
<b>Mediating Volumetric Thresholds</b> . . . . .	211
Gabriel Fries-Briggs	
<b>Instruction and Instinct</b> . . . . .	223
Emmanuel Vercurysse, Kate Davies, Tom Svilans and Inigo Dodd	
<b>Objects of Rotation</b> . . . . .	233
Rachel Dickey, Jili Huang and Saurabh Mhatre	
<b>D-FORM</b> . . . . .	249
Renate Weissenböck	
<b>Experiments in Additive Clay Depositions</b> . . . . .	261
Jared Friedman, Heamin Kim and Olga Mesa	
 <b>Part III Workshops</b>	
<b>Core-Less Filament Winding</b> . . . . .	275
Marshall Prado, Moritz Dörstelmann, Tobias Schwinn, Achim Menges and Jan Knippers	
<b>Adaptive Part Variation</b> . . . . .	291
Lauren Vasey, Iain Maxwell and Dave Pigram	

Contents	xiii
<b>All Bent Out</b> . . . . .	305
Thibault Schwartz, Joshua Bard, Madeline Ganon, Zack Jacobson-Weaver, Michael Jeffers and Richard Tursky	
<b>Design Approaches Through Augmented Materiality and Embodied Computation</b> . . . . .	319
Ryan Luke Johns, Axel Kilian and Nicholas Foley	
<b>Material Feedback in Robotic Production</b> . . . . .	333
Felix Raspass, Felix Amtsberg and Stefan Peters	
<b>Phase Change: Approaching Research Methodologies Through Design Robotics</b> . . . . .	347
Nathan King, Kadri Tamre, Georg Grasser and Allison Weiler	
<b>Sense-It</b> . . . . .	357
Ellie Abrons, Adam Fure, Alexandre Dubor, Gabriel Bello Diaz, Guillem Camprodon and Andrew Wolking	
 <b>Part IV Industry Papers</b>	
<b>KUKA Robots On-Site</b> . . . . .	373
Stuart Shepherd and Alois Buchstab	
<b>ABB Robotic Technology in Art and Industry</b> . . . . .	381
Martin Kohlmaier, Nicolas De Keijser and John Bubnikovich	
<b>Special Solutions for Special Applications</b> . . . . .	387
Joe Gemma and Manfred Hubschmann	
<b>Sensitive Robotic Processes</b> . . . . .	393
Christian Binder	
<b>The Power of Engineering, the Invention of Artists</b> . . . . .	399
Kendra Byrne, Jonathan Proto, Brandon Kruysman and Matthew Bitterman	
<b>Robots in Architecture 2014 Scientific Committee</b> . . . . .	407