

Preface

From Robotic Fabrication to Creative Robotics

The adoption of digital fabrication in the creative industries continues to accelerate as the potential for innovation and creative expression using robotics is harnessed. Following the conference theme of “Trajectories” the research presented in this book demonstrates the continuing evolution of robotic fabrication and creative robotics in architecture, art, and design—toward the integration of human–robot interactions informed by sensor input and real-time feedback under diverse environmental conditions.

Developed for factory automation, industrial robots offer accuracy, flexibility, and reliability with reduced operational costs. For these reasons, artists and designers seeking to explore and expand the possibilities of computational design, parametric modeling, and real-time sensor feedback have enthusiastically adopted industrial robots. The efforts of early pioneers in the field and the adoption of open standards for programming and connectivity by manufacturers have lowered the barriers to exploring the creative application of industrial robotics, allowing even more creative practitioners to get involved. Digital fabrication combined with open-source hardware and software has opened up the development of novel technologies, interfaces, and methods to interdisciplinary teams of designers, artists, and engineers.

Creative robotics offers new insights into the potential of robotics as researchers and practitioners explore novel approaches to fabrication and interaction with robotics. The flexible nature of industrial robotics presents an opportunity to reconsider the entire design-to-production process, while the integration of real-time sensor feedback has created opportunities for working with new materials and processes that bring design and production closer.

Rob|Arch 2016

Initiated by the Association for Robots in Architecture as a conference series focusing on the use of robotic fabrication within a design-driven context, the now established biennial Rob|Arch conference for 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. Launched by its founders Sigrid Brell-Çokcan and Johannes Braumann in Vienna, Austria as Rob|Arch 2012, the Rob|Arch 2014 conference traveled to University of Michigan, Taubman College of Architecture and Urban Planning, USA. In its third iteration, the Rob|Arch 2016 conference arrives in Australia, hosted by the Faculty of Architecture, Design and Planning, The University of Sydney: Australia's first university and academically known for its multidisciplinary design education and long-standing tradition of knowledge creation.

Research and Discussions

Robotic Fabrication in Architecture, Art, and Design is first and foremost a platform for sharing research developed across the field of robotics, undertaken by designers, artists, and architects, by researchers and educators, in academia and in practice and industry, and by innovative forms and start-ups. Consequently, the call for papers, together with the call for workshops and invited keynotes and industry papers, reflects this open agenda.

Keynotes, Research and Project Papers

This publication presents a series of key sections that contribute to the Rob|Arch 2016 conference and workshop discussions; the invited keynotes, the research and project papers, the workshop papers, and the industry papers.

The two keynotes address the conference theme of “*Trajectories*” in a dialectical discourse. Mark Burry traces the development of material practices in Gaudí's Sagrada Família from the century-old art of stereotomy toward 7-axis robotic stone-cutting. Francois Roche's mediation of new prosthetic entities breaches the territory of conventions and expectations for robots as we have previously understood them toward uncertain processes and protocols of interactive behavior.

In the research and project papers, a number of themes emerge with the scientific paper submissions for this year's conference, which continue robotic fabrication research and expand toward sensor-enabled processes and robotic interaction. Amongst those, the aspect of engineering structures as a direct transfer from

computational modeling to robotic manufacturing of joints, deposition of material, or assembly plays an increasing role.

Assembly strategies are discussed here that include strategies of aerial robotic construction; autonomous robotic assembly with virtual storage of material data; the location-aware robotic laying of a brick wall; a cable robot system with visual dynamic feedback for on-site construction; robotic assembly prototyping with sensor-enabled material selection of components; and include a survey of scanning techniques for surface descriptions in robotic assembly.

New material and work techniques developments with strong interest in structure include a further advancement of robotic incremental sheet forming toward a frameless stressed skin structure; the robotic smocking of sheet metal as developable surfaces; approaches for robotic enabled stress-line additive manufacturing in curved surfaces; or the robotic 3D printing as compression-based material deposition; and the robotically assisted welding of a grid shell structure.

Flexible and adaptive additive manufacturing strategies are presented as the robotic multidimensional weaving print based on structural performance; and the robotic positioning of a flexible fabric formwork. Fabrication and specifically the detailing of joints for stabs, plates, and modules are discussed; in the folded plate shell with double through tenon joints; as multidimensional finger-joint in a rib structure module; in the topology optimization and robotic fabrication of timber space-frame structures; as wave jointed stereotomic construction; and extended toward industrial application in a robotic fabrication of a free-form ceiling structure. Toolpath planning plays an increased role for customizable stone structuring patterns; and for the micro-design of acoustically efficient disks.

The robotic hot blade cutting of double-curved geometries is presented here in an 18-axis, tri-robot system for the cutting of doubly curved surfaces; as robotic blade cutting of customized components for acoustic panels. Processes for mass-customizable formwork for free-form geometries for mold fabrication include the testing of reusable adaptive production strategies for concrete constructive elements; the continued fabrication of formworks for deposition of ceramic 3D printing, and the 3D printing of interlocking modules.

And finally, real-time and recursive feedback between algorithms, robot, and material are explored as multiple-agent and robotic fabrication prototypes; the integration of smart technologies and sensor loops in a multidisciplinary, open design, and collaboration platform.

Workshop Papers

The practical hands-on workshops are a core part of the Rob|Arch conferences, allowing individuals and teams from around the world to collaborate with leading researchers and practitioners from academia and industry. The workshops foster research networks across international teams of researchers and practitioners to exchange knowledge about this exciting field and to speculate on future trajectories.

Many of the workshops represent cutting-edge research and practice under development and the workshop papers in this book present the ideas behind these workshops in detail.

The selected workshops cover a diverse set of experimental approaches to robotic fabrication from real-time human–machine interaction to novel form finding strategies. The workshop from the Southern California Institute of Architecture explores user interfaces for live robotic control such that creative practitioners can continuously engage and adapt to an evolving context. A collaborative team from HAL Robotics, Bond University and Sounddisplay presents an approach to natural human–machine interactions for context-specific object recognition in collaborative robotics via ad hoc communication using voice and gestures. The paper from RMIT explores an agent-based model of generative fabrication to imbue physical material with digital agency with the aim of collapsing design and fabrication processes. The paper from IAAC, Make It Locally and The University of Sydney presents a framework for understanding the evolution of feedback loops within human–machine–material interactions in robotic fabrication workflows as sensors are introduced into processes. The workshop from the team from the University of Technology Sydney and the University of Michigan explores the potential for expanding traditional architectural form finding processes by embedding algorithmic design methods and robotic fabrication strategies.

Industry Papers

As in previous years, the industry papers provide a strong voice from the Rob|Arch 2016 industry, partners and sponsors, and more excitingly so, this time bridging between continents, from Europe over to the United States to Australia. These papers offer insights into the most recent industry developments in the context of robotic fabrication. KUKA presents the LBR iiwa, and the new mxAutomation interface that allows direct robot control in interaction with modern industrial real-time communication, and thus enables entirely new, flexible workflows from design to production towards fabricating highly customizable products in the creative industry. ABB showcases collaborative robotics with its new series of sensitive robots—the ABB YuMi—that can assemble and collaborate safely with humans due to the ABB ForceControl which allows robots to react to the forces that are applied to their end-effectors. Autodesk presents the application of its novel visual scripting interface Dynamo for a collaboration and robotic fabrication workflow of the construction of spatial structures. SCHUNK shows an approach for efficient creation of form-fitting and flexible gripper design. ERNE Holzbau reports on one of the largest robots for building component manufacturing in Europe; a multifunctional 7-axis machine that can manufacture large building components on an industrial scale. Delcam presents the PowerMILL Robot, a software system that provides an easy to use computer interface allowing the programmer to design, analyze, and simulate in a single virtual environment.

Outlook

Reflecting the theme of the conference, a number of trajectories can be identified from the work presented in this volume that offer insights into the future of robotic fabrication in architecture, art and design.

The integration of sensors into robotic fabrication continues to be a theme that has run through the Rob|Arch conferences to date, from enabling tolerance for material and environmental variability in the fabrication process, essential for on-site construction robotics, to assisting with the planning of workflows and the live control of robotic systems. Beyond the integration of sensors, the increasing application of intelligent control systems take advantage of the feedback at different scales, increasing the level of autonomy of the robotic systems and opening up new materials and processes that require constant monitoring and adaptation. Beyond the current state-of-the-art of robotic fabrication there lies creative robotics, the evolution of an embodied computational creativity capable of sustained creative practices without human intervention—opening up new horizons for human-machine collaboration.

Advances in sensors and intelligent control systems have highlighted the agency of materials in the fabrication process, both as a result of the increased sensitivity of robotic systems to the effects of machining and the ability of robotic fabrication systems to react to changing environmental conditions. Perhaps seeing the start of a generational change in thinking about construction automation, we are increasingly seeing researchers radically rethinking how we shape our environment through different forms of robotic fabrication. The scale and ambition of these approaches is increasing with every conference cycle and we can look ahead to a future where robotic fabrication will change every aspect of our built environment from the smallest component to whole cityscapes.

Industrial robots provide the ideal platform for experimenting with fabrication processes being both flexible to changing requirements and standardized across working environments to support the transfer of new knowledge between research groups. In this third iteration of the Rob|Arch conference, we continue to see the benefits of the knowledge transfer between researchers, practitioners and industry partners. In particular, the opening up of industrial robotics to experimental approaches and creative explorations is dramatically accelerating progress in the field. As new robotics technologies are developed, researchers and innovators in the creative industries will continue to adapt these tools and transform practices to take advantage of the opportunities they bring. The potential of adopting new automation methods, especially robotics, has become part of the public discourse on the future of work as part of a second industrial revolution. Within the creative industries robotics fabrication is affecting the whole design process, to the point of challenging what it means to “design.”

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