Title: Robots in Architecture – Making Robots Accessible to the Creative Industry

Presented by: Johannes Braumann, Association for Robots in Architecture and University for Arts and Design Linz

Authors: Johannes Braumann (Association for Robots in Architecture and University for Arts and Design Linz) and Sigrid Brell-Cokcan (Association for Robots in Architecture and RWTH Aachen University)

Description: The presentation showcases how the development of intuitive interfaces and the support of a network of users turned robotic arms from high-end machines that are only seen in large-scale companies into innovation drivers for the creative industry. Today, the software tools developed in the creative industry are even used at large companies to quickly prototype new, non-standard robotic processes.

Keywords: industrial robots, creative robotics, interfaces, visual programming, network

Biography: Sigrid Brell-Cokcan and Johannes Braumann co-founded the Association for Robots in Architecture in 2010 with the goal of making industrial robots accessible to the creative industry. Headed by Sigrid Brell-Cokcan and Johannes Braumann, it acts on the one hand as a network for robot users worldwide by organizing the biannual Rob|Arch conferences (proceedings published at Springer) but also as an active research institute, having been involved in a large range of both national and EU research projects (FWF, FFG, EU-FP7). RiA has been instrumental in creating a topic group for Construction Robotics at euRobotics, and has initialized the Construction Robotics Journal at Springer. The Association makes its KUKA|prc software for accessible and intuitive programming of KUKA robots available through its homepage, which has been a determining factor towards bringing easy robot programming into ateliers, offices, and classrooms.

Introduction

Robotic arms, or industrial robots, have become indispensable for many fields of industry in Europe. Commonly used for spot-welding, palletizing, or other repetitive tasks, these machines were initially mostly found within the automotive industry, but are today seeing increasingly wider applications. Their significant advantage over conventional machines is their inherent multifunctionality: Similar to the human hand, they can be equipped with a large variety of tools, from welding equipment to gripping tools. As a mass-produced product, they are comparably affordable, come in many variations and are designed to be highly durable, capable of several years of 24/7 operation.

For a long time, architects and designers have admired the perfect synchronization of an automotive production line (Figure 1). However, creative users always depended on external assistance by robotic engineers, programmers, or mathematicians, limiting intuitive interaction and experimentation with robots.

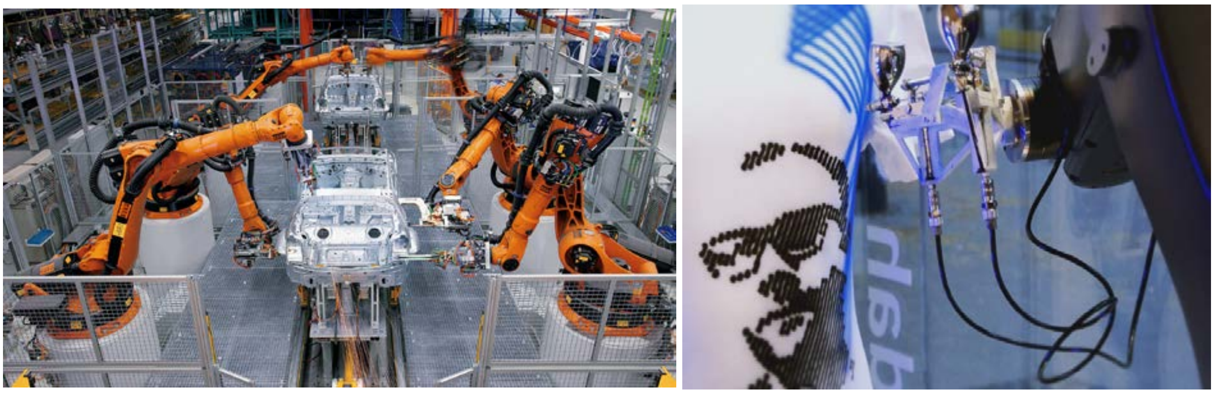

Figure 1: Robotic mass production in industry (left), individual, spray-painted portraits by Robots in Architecture for Absolut (right, https://vimeo.com/94077180).

The main challenge towards using robots within the creative industry is that the creative industry is mostly interested in mass-customization, i.e. the efficient manufacturing of many different parts, such as individual façade panels for a free-formed high-rise building where no panel is identical, whereas the focus of the core-robotics industry used to be primarily mass-fabrication. Therefore, software tools for robot programming are targeted at high-end users that would spend several days or weeks on creating a highly-optimized product, but not so much on efficient prototyping or creative form exploration. Furthermore, commercial software capable of programming robotic arms only exists for a few prominent applications such as milling through CAM (Computer Aided Manufacturing) software.

New and innovative processes developed for industrial robots require the development of entirely new fabrication strategies or data interfaces to import data from other, specialized software. As such, one of the biggest challenges in realizing these new fabrication concepts lies in the data flow – most often the linking of geometric data with fabrication data.

Towards Intuitive Interfaces for Robots

In our own research, we received a KUKA robotic arm as part of a research project on multi-axis milling, along with high-end CAM software for toolpath generation and a simulation environment by KUKA that allowed us to import generic machine-code from the CAM tool and turn it into robot code. However, teaching these different tools to architecture students proved complicated, as it took nearly the entire semester to move from the CAD (Computer Aided Design) to a physical output. When the simulation software showed a problem with the toolpaths, we had to go back to the CAD environment, change the geometry, export it again to the CAM software and regenerate the toolpaths, until we could check the robotic process again within the simulation environment. This made the interaction with the robot very slow, especially as licensing did not allow students to use the software on their own laptops.

At that time, the visual programming environment Grasshopper was gaining popularity in the creative industry. Built on top of the very widely used CAD software Rhinoceros, Grasshopper allows users to define parametric relationships between geometry by connecting components that can contain geometric, mathematical, or other operations. The advantage over other systems is that the results of such a parametric definition are immediately displayed in the viewport, allowing for a quick and intuitive interaction with the model.

By integrating robot-specific functionality – a kinematic solver, different types of robots, a generator for KUKA Robot Language – as native Grasshopper components written in C#, we are not limited anymore to linking geometric parameters together, but can connect geometry directly with fabrication (Figure 2). Thus, whenever the geometry changes, the viewport does not only show the updated geometry, but also how it affects the robot's toolpath. On the one hand, this allows the efficient fabrication of parametric objects, i.e. objects that are based on a common set of rules, but allow customization by the user, but especially enables a very rapid learning process, as the user can immediately see the results of his actions and react accordingly, rather than having to go through a long workflow involving several different programs.

The resulting software for robot programming and simulation was made available as KUKA|prc (parametric robot control) through our homepage and has since been continuously improved and developed, based on the feedback from both industry as well as creative users.

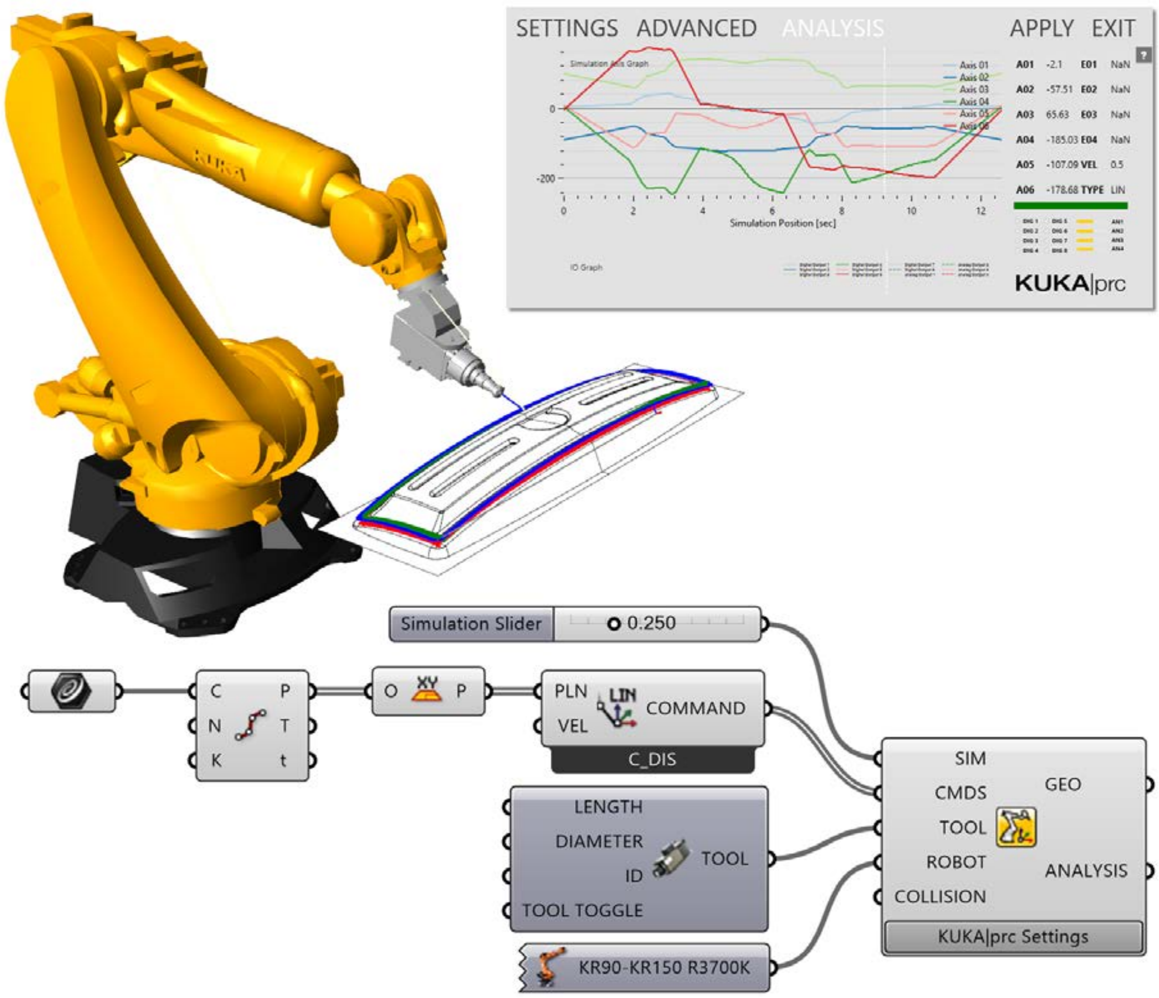

Figure 2: Accessible robot programming and simulation using Grasshopper and KUKA|prc.

Our current research focuses on even more streamlining the link to robot. Building upon the KUKA software mxAutomation, we can directly stream data to the robot via Ethernet. By doing so, the parametric design environment takes over the part of the robot controller, allowing highly interactive robotic applications. The idea is to turn the robot into a peripheral device, a machine that you simply connect with your PC and can then control remotely.

Enabling Creative and Industrial Applications

In the past years, the creative industry has attempted to take fabrication back into their own hands and away from outsourced factories. As such, an area of special interest is the idea of customized robotic labor, away from mass fabrication and towards individualized products that are still manufactured with great efficiency. One of the most important tools in that regard are 3D printers, which have become highly popular and subsequently dropped steeply in price, making extrusion-based processes accessible to enthusiasts. However, these machines have in common that their workspace is significantly limited and that their cycle speed is inherently slow, being an additive process where material has to harden in order to support the next layers. Therefore, the move from scale model to full-sized industrial-design prototypes or architectural building components required expensive, large-scale machines that were often out of the reach of the creative industry.

Now, *industrial robots* have started to fill that void by enabling the creative industry to work on a scale that exceeds desktop-CNC machines. Using KUKA|prc, several companies have been able to create completely new, large-scale processes that previously would have required the support of many engineers and professionals. One example is Branch Technology (Figure 3), a start-up in the US that has developed a large-scale, robotic 3D-printing process for the construction industry. Rather than building up a geometry layer-by-layer, they are constructing a complex, threedimensional framework structure. As there is no commercially available software capable of generating either the geometry or the machine code for such an application, they have developed their own algorithms within Grasshopper and rely upon KUKA|prc to get an accurate simulation of the robot, as well as generate the robot code to drive the process.

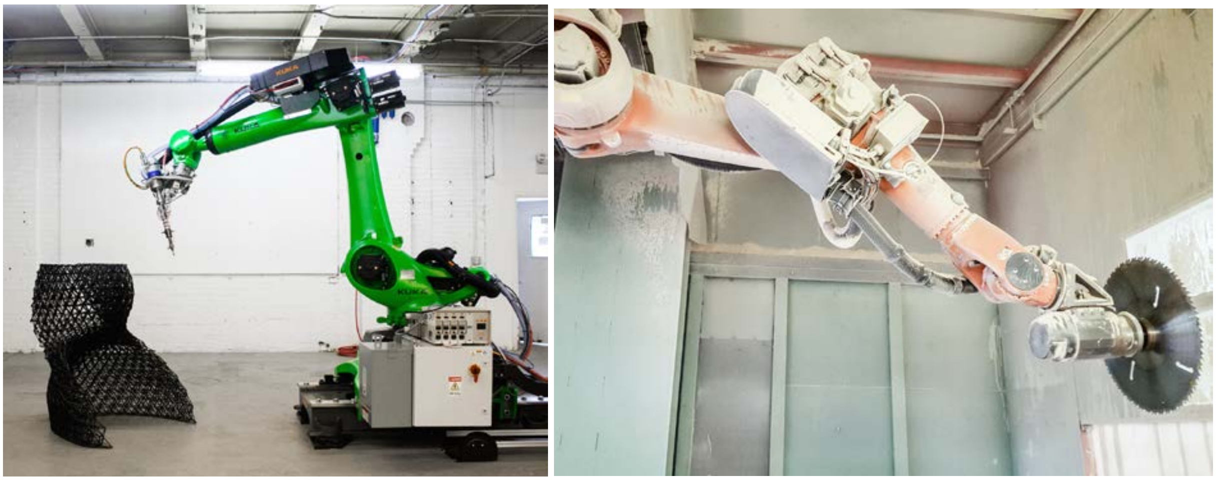

Figure 3: Robotic 3D printing at Branch Technology (left), large scale commercial milling (right).

The same strategies are now also gaining popularity in industries outside the creative sector, with e.g. a large wood construction company in Germany now using KUKA|prc to control a building-scale robotic setup that is capable of milling panels as large as 40x5m. By using a visual programming environment rather than regular CAM software, they are able to implement their own, specialized material and manufacturing knowledge into a process, rather than being limited to pre-set fabrication strategies from CAM software. Companies such as Boeing and Adidas are also utilizing KUKA|prc for quickly and efficiently prototyping robotic processes within their development departments.

Connecting Industries

While accessible robot programming and simulation software has been an important factor towards making industrial robots more accessible, operating a robot requires more knowledge than using a simulation environment. Thus, a very important aspect has been the development of a community that would link industry with creative users and allow an active conversation, as well as an exchange of ideas and innovations. With that goal in mind, the Association for Robots in Architecture set up the first Rob|Arch conference in Vienna in 2012, for the first time bringing together creative users with members of industry, and offering conference workshops at several robotic labs throughout Europe. The conference has since also taken place 2014 in Michigan and 2018 in Sydney, with the next conference scheduled to take place at ETH Zurich in 2018. The Association has since then also become actively involved in euRobotics, the EU's public-private partnership for robotics and co-founded the Construction Robotics topic group towards putting additional funding into robotics research for construction. A Springer journal on Construction Robotics is upcoming.

Outlook

Even though robotic arms have been on the market for more than 30 years, we believe that industrial applications are often not realizing the full potential of these complex machines. By developing tools that make industrial robots more accessible, as well as acting as a network for creative robot users around the world, we are bringing in a large range of new users with fresh ideas into the diverse field of robotics. Through this process, we are seeing launches of exciting start-ups, but also large companies embracing new technologies.

Recently, we have launched the Creative Robotics Laboratory at the University for Arts and Design in collaboration with KUKA Robotics and the Ars Electronica Center. Equipped with several KUKA robots of different sizes, we are exposing students of all programs to robotic fabrication at an early stage as well as exploring new robotic processes with industry partners.

Relevant References

Brell-Cokcan S. and J.Braumann (eds.). (2012). Rob|Arch: Robotic Fabrication in Architecture, Art, and Design. Vienna: Springer.

Braumann, J. and S. Brell-Cokcan. (2011). Parametric Robot Control: Integrated CAD/CAM for Architectural Design. In ACADIA 11: Integration through Computation: Proceedings of the 31st Annual Conference of the Association for Computer Aided Design in Architecture, 242-251. Banff (Alberta).

Braumann, J. and S. Brell-Cokcan. (2015). Adaptive Robot Control. In Proceedings of the 2015 eCAADe Conference

Braumann, J., S. Stumm, and S. Brell-Cokcan (2016). Towards New Robotic Design Tools. In Proceedings of the 2016 ACADIA Conference