Robotic Woodcraft

Creating Tools for Digital Design and Fabrication

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Robotic Woodcraft is a transdisciplinary, arts-based investigation into robotic arms at the University for Applied Arts Vienna. Bringing together the craftsmen of the Department for Wood Technology, the geometers of the Department for Arts and Technology, the young industrial design office Lucy.D and the roboticists of the Association for Robots in Architecture, the research project explores new approaches on how to couple high-tech robotic arms with high-end wood fabrication. In the eCAADe workshop, participants are introduced to KUKA|prc (parametric robot control, Braumann and Brell-Cokcan, 2011) and shown approaches on how to create their own digital fabrication tools for customized fabrication processes involving wood.

Keywords: *Robotic woodcraft, Arts-based research, Robotic fabrication, Visual programming, Parametric robot control*

INTRODUCTION

Through advances in programming interfaces and increasingly affordable hardware, robotic arms have become relevant tools for the creative industry within a very short timeframe. As a modular system, they can be equipped with a huge range of tools (Figure 1) and thus be used in a similarly huge spectrum of applications. We see a particular potential for robotic arms in the area of high-end wood fabrication: As a non-homogenous, anisotropic material, wood can be processed in many different ways, from regular milling to more complex applications such as bending and even additive processes (refer e.g. to Menges, 2012 and Gramazio et al., 2010). At the same time, being a grown material that expands and contracts with the level of humidity, wood fabrication

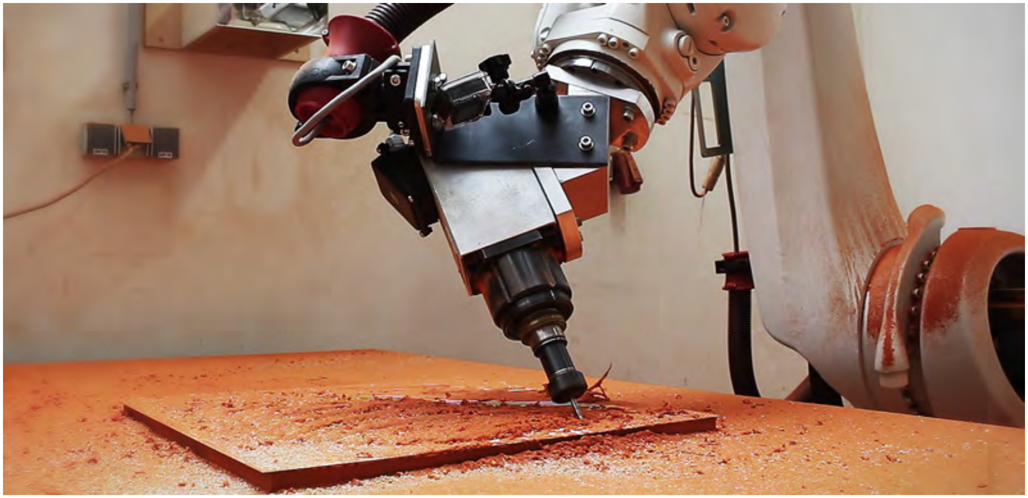


Figure 1
Multi-axis flank milling of an art installation in cooperation with design studio Lucy.D, Vienna.

requires less rigid tolerances than metal fabrication, where robots cannot compete with the accuracy of dedicated metal milling machines.

Visual programming environments, especially Grasshopper, coupled with robot control plugins such as KUKA|prc, today enable us to dynamically define, simulate, and execute complex, robotic processes that go beyond standard-milling applications (Braumann and Brell-Cokcan, 2014). Thus we are not limited to certain pre-defined milling strategies, but can integrate the special, anisotropic material properties into our code.

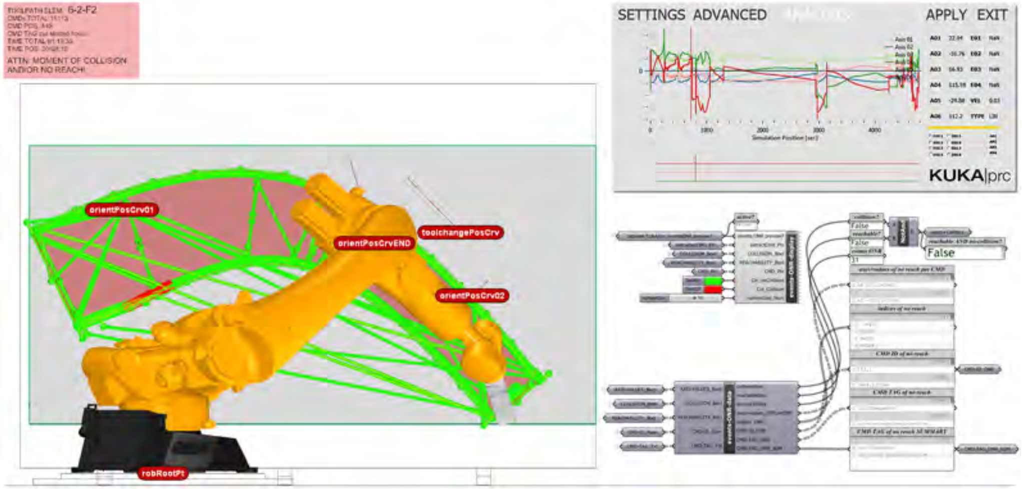
CUSTOMIZED DESIGN TOOLS

KUKA|prc provides us with the essential software tools for robot simulation and code generation. However, for complex tasks we have to create custom design tools that integrate certain special properties and parameters. Due to Grasshopper's modular, component-based system, these strategies can therefore be contained within their own components that expose only the relevant input and output ports. The following tools are based on native GH-components, VB-script as well as components by KUKA|prc.

kukaFeeds When working with an anisotropic material like wood and material-optimized cutters, machining velocities are of great importance. To be able to handle different scenarios with their specific speeds a custom component was developed. It defines machining related velocities like e.g. rapid velocity for movements to, from and above material, plunge velocity for movements cutting into material, retreat velocity out of material as well as the milling velocity for cutting in material. Unlike commercial CAM (Computer Aided Manufacturing) software, these properties can then be finely adjusted, e.g. for each individual toolpath, rather than applied globally.

revCrvs | revPlns | revLT The resulting quality and final finish of machined contours or surfaces are directly dependent on the internal structure (radial, tangent or axial orientation of fibers) of the initial material (wood) as well as the direction of cut itself (Figure 1). To enable a quick assignment of specific directionality to a custom designed toolpath three different components (reverse curves, reverse planes, reverse lists-tree) were designed.

Figure 2
events-ONR-data | events-ONR-display: quantitative and qualitative summary of unreachable positions or collisions (refer to Braumann, Brell-Cokcan 2015).



events-ONR-data | events-ONR-display When handling many complex toolpaths in one continuous process, the resulting data-set within the planning environment is rapidly increasing. As a consequence, it becomes increasingly difficult to maintain an overview of the project, possibly causing one to miss problematic robot positions. Therefore, out-of-reach positions as well as collisions have to be prechecked to avoid kinematic singularities, collisions, or damage to the robot and its surroundings. For a fast quantitative and qualitative summary two components were developed (Figure 2). In the event of unreachable positions or collisions, the *quantitative outputs* display the amount, of 'events ONR' (events of no reach and collision), the related axes, axis-values, indices, command ids and command tags. These outputs greatly facilitate spotting affected situations in the toolpath as well as on the programming canvas of Grasshopper. As an additional feature, 'events ONR' can be displayed graphically in the rhino viewport.

customToolKressElte Special tools allow us to perform operations that would not be possible with regular, commercial end-effectors. A special mount for a compact Kress spindle was developed by analyzing the limits of our large milling spindle with the goal of creating a complementary tool for situations with complex reachability. Its digital representation allows us to digitally evaluate such situations in advance and avoid collisions with the workpiece (Figure 3).

customToolElte+Fipa Similarly, a custom physical tools was developed that allows us to combine gripping and milling in one seamless process. It is based on a mid-sized electro spindle (Elte TMPE4) and an overhead-mounted vacuum gripper (Fipa TC120x230) on multiple custom flange elements. In many industrial applications, robots are only used for pick and place operations - with new, custom tools this could be easily expanded, but also requires new programming approaches that can cope with the complexity of having multiple tools mounted onto a single machine.

CONCLUSION

Visual programming has allowed us to quickly and efficiently create robotic processes that embed parts of the material knowledge of artisans and carpenters

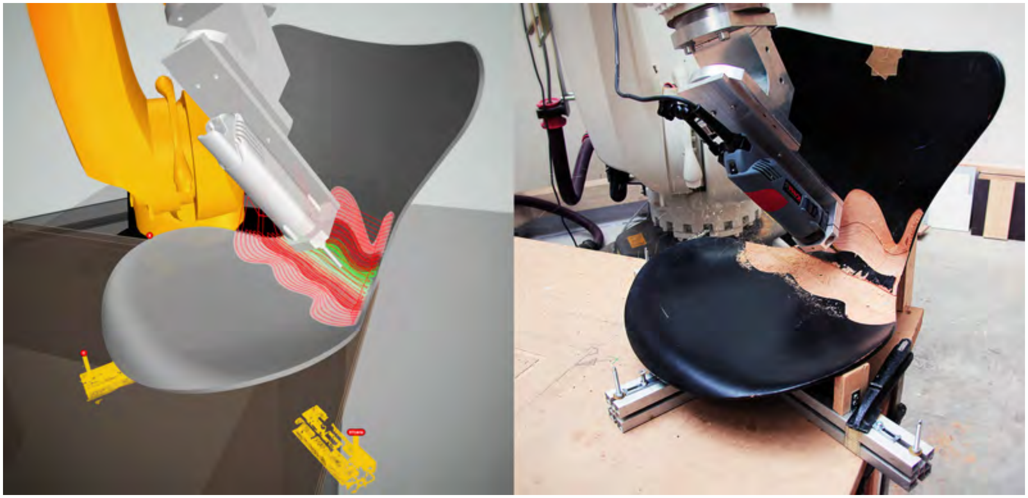


Figure 3
Freeform surface machining of a double-curved plywood shell in cooperation with Rüdiger Suppin, TU Vienna, entitled 'Repair My Series 07'.

within the code, making it accessible to non-expert users (see also Brell-Cokcan and Braumann, 2014). Similarly, we can now quickly prototype new robotic tools within a virtual environment, greatly speeding up their development.

Therefore custom software allows us to move past the limitations of commercial software, which is generally not optimized for materials with a complexity like wood, towards new robotic applications.

We expect that the use of robotic labor will continue to have a deep impact on the creative industry, towards creating new and customizable designs with multifunctional machines and the similarly multifunctional material wood.

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