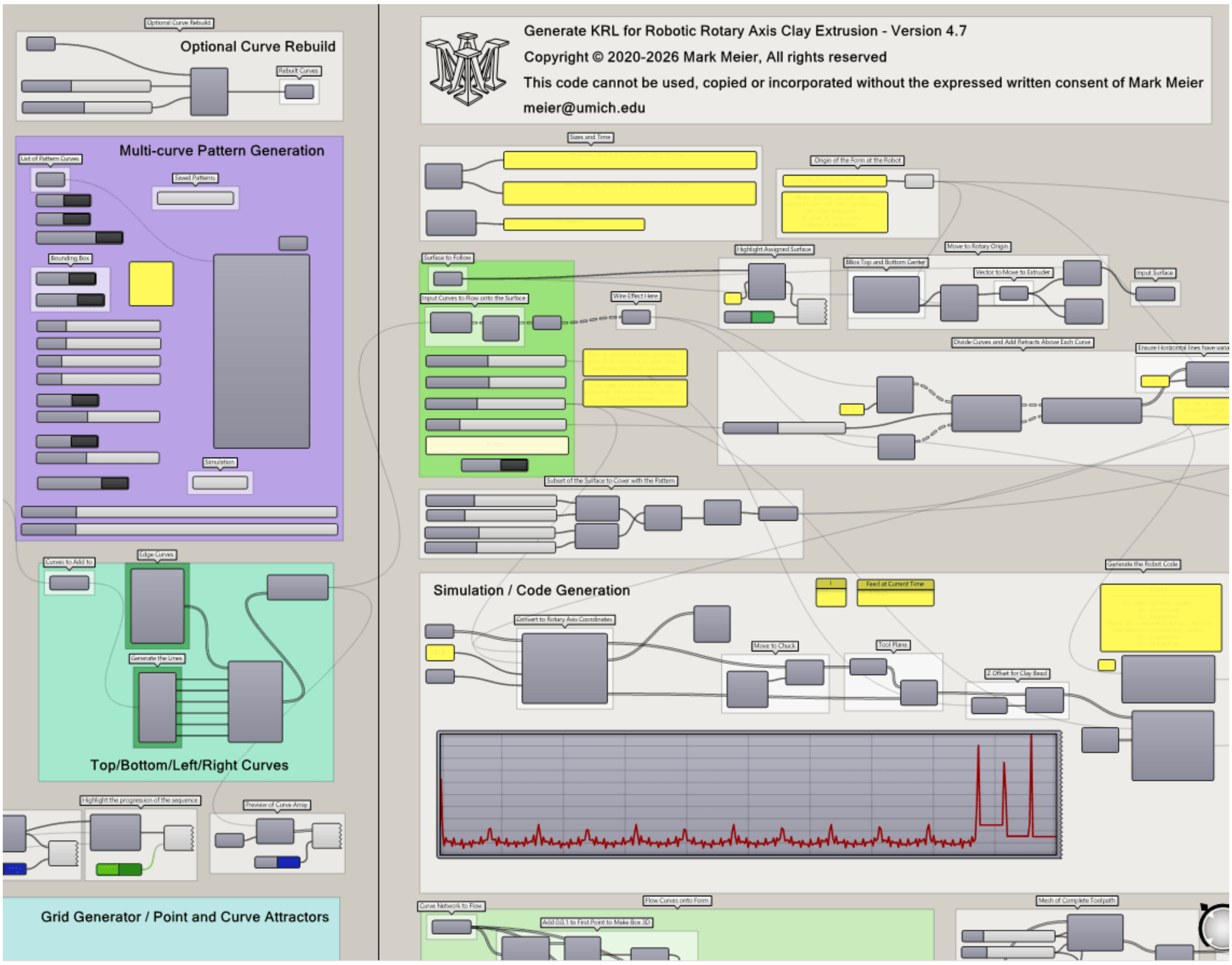
Continuous Curves, Rotating Forms: A New Approach to Ceramic Printing

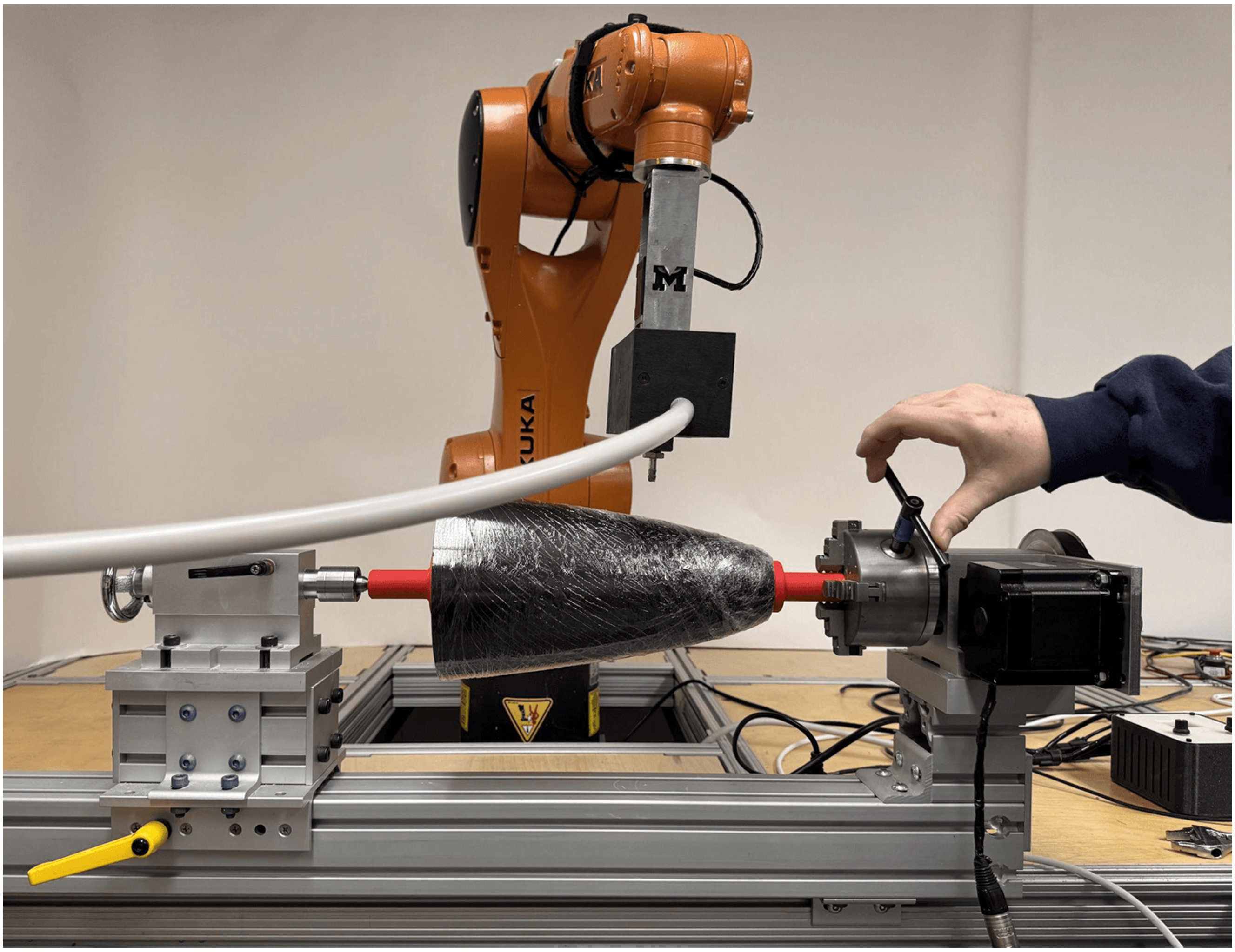
Rather than treating ceramic 3D printing as a process of stacking horizontal layers, Mark Meier has developed a fabrication method that approaches clay extrusion more like drawing in space.

Using a KUKA KR-6 robotic arm, a custom clay extruder, and a lathe-like rotary axis, the system deposits a continuous bead of clay onto a rotating 3D-printed form. The result is a family of unusually light and open ceramic structures whose intricate geometry emerges directly from the coordination of digital design, robotic motion, and material behavior. The research was developed at the University of Michigan Taubman College Fab Lab, where Meier teaches and conducts research.



The Grasshopper definition developed to generate surface patterns, simulate the fabrication sequence, and produce KRL code for the robotic rotary-axis extrusion process.

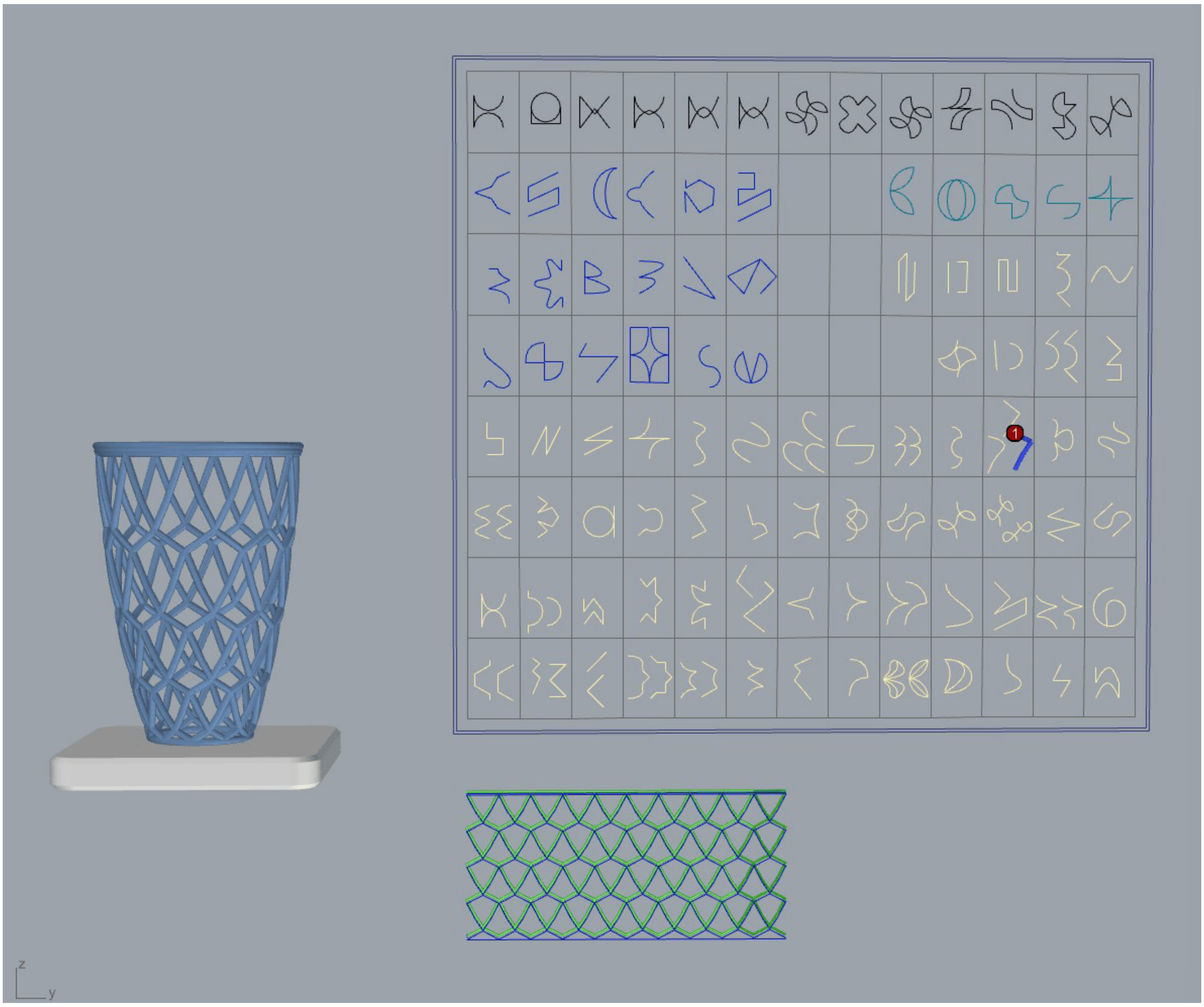
At the center of the workflow is a close relationship between Rhino, Grasshopper, and Python, with each tool taking on a specific role.



The physical fabrication setup pairs a KUKA robot with a custom rotary axis and reusable formwork, translating the digitally simulated workflow into a working clay extrusion system.

Rhino is used to model the 3D forms that support the clay during printing and to draw the initial pattern curves. In Grasshopper, those base curves are repeated, mirrored, and sequenced to generate larger continuous patterns. The resulting geometry is then mapped onto the modeled surface, transforming a two-dimensional motif into a toolpath that follows the three-dimensional form.

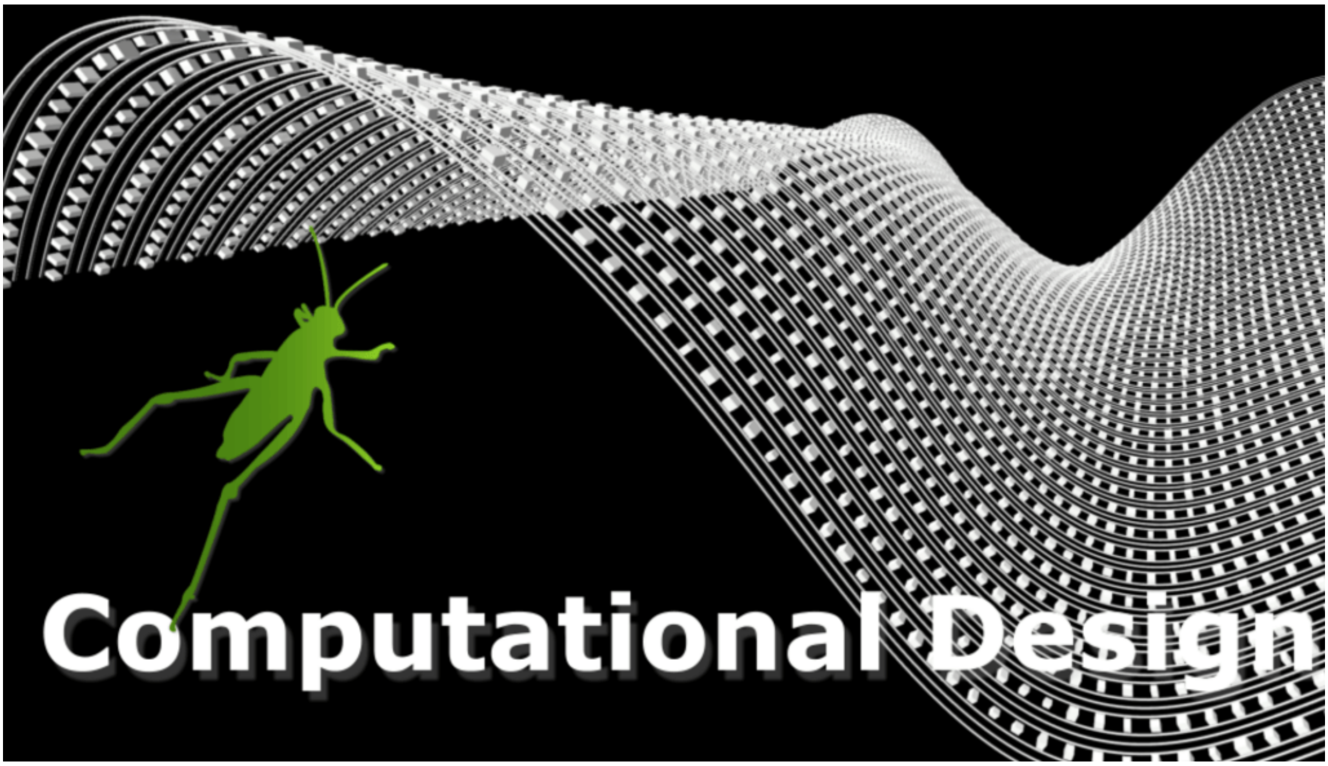
This continuity is critical. Because the clay extruder performs best when material flow remains constant, Meier developed Grasshopper tools specifically to generate complex patterns from a single continuous bead of clay, reducing the need for repeated starts and stops.



A library of curve-based pattern studies in Rhino explores how different motifs can be repeated and mapped across the surface of a rotating form.

The fabrication setup adds another layer of complexity. The support form is mounted horizontally between a chuck and tailstock on a custom rotary fixture. As the robot moves the extruder, the form rotates simultaneously, allowing the printhead to trace patterns around the entire surface rather than simply building upward in conventional layers.

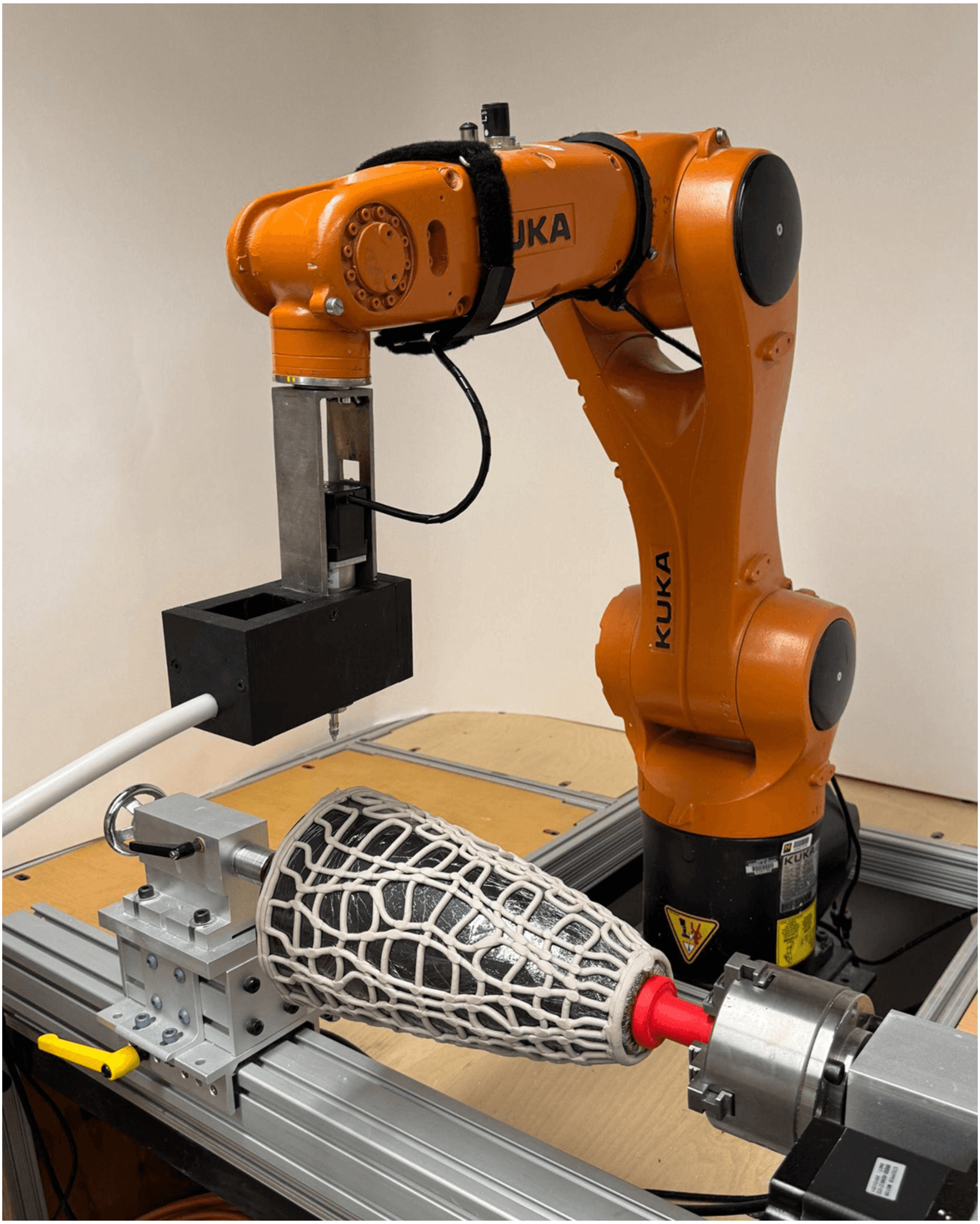
Before fabrication, the robot motion can be simulated to verify reach and avoid problematic positions; [KUKA|prc] is used within Grasshopper for simulation and toolpath generation.



See Also

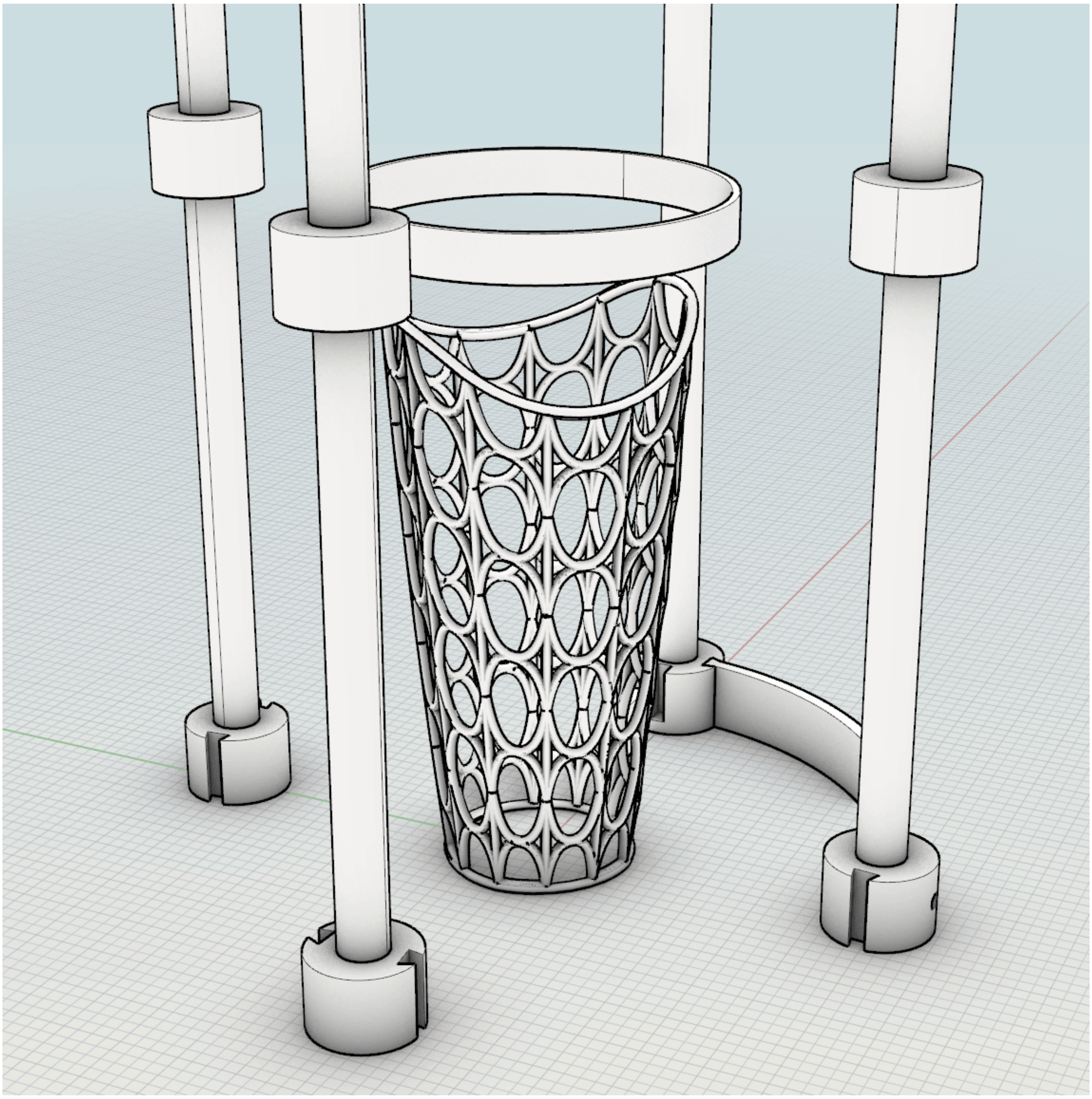
COMPUTATIONAL DESIGN WITH GRASSHOPPER

Python handles one of the most technically demanding parts of the process. A Python component inside Grasshopper generates the toolpath and rotary-axis rotations required to synchronize the position of the rotating form with the movement of the robotic arm. Achieving that synchronization required extensive experimentation and repeated adjustments to the Python code.



Clay is extruded directly onto the rotating form as the robot and rotary axis move in coordination, building the open lattice without conventional horizontal layer stacking.

Material flow presented a parallel challenge. The custom extruder uses components from [3D Potter] and [StoneFlower 3D], while its motors are controlled through custom electronics programmed in [CircuitPython](). Maintaining a consistent clay extrusion rate while coordinating the robot and rotary axis became one of the key areas of testing during development.

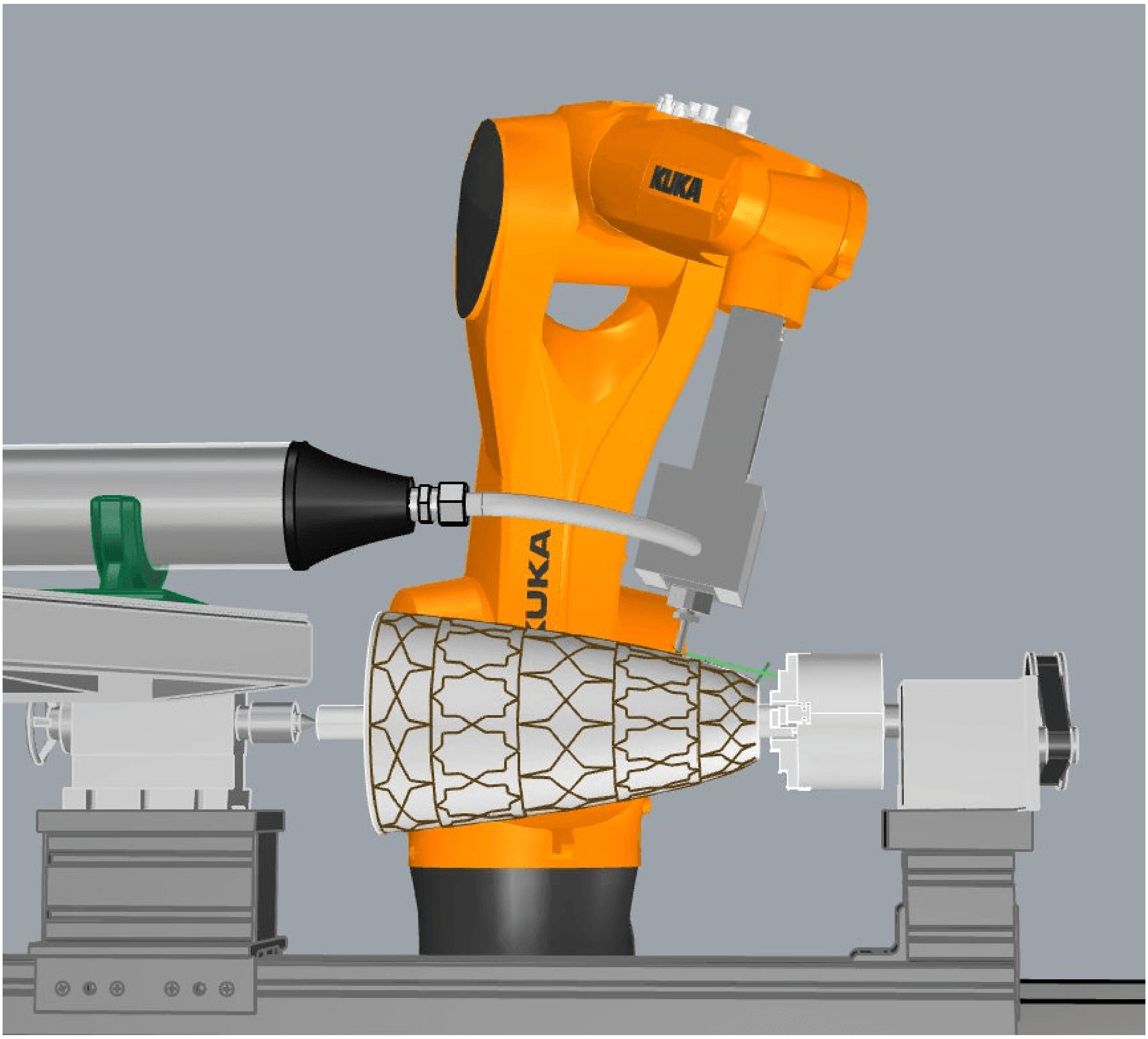


A Rhino model of the support fixture developed to hold the printed ceramic structure while it is separated from the underlying form and prepared for subsequent processing.

The physical formwork is equally considered. Each support form is 3D printed in plastic and wrapped in a thin plastic film before printing. The clay adheres to the film during deposition, but once the printed structure has firmed up for roughly 15–30 minutes, the film can be slid off the rigid form. The still-fragile ceramic shell is then suspended in a custom fixture and left to dry overnight, allowing it to shrink without the rigid mold constraining or distorting it.

A freshly printed clay structure held within the support fixture, illustrating one of the practical challenges of handling the delicate geometry before firing.

Once dry, the pieces are bisque fired, glazed, and fired again. Meier has explored the process through vases, tool cups, and lighting fixtures, but the real outcome of the research is broader than any one object: a new way of thinking about robotic ceramic printing.

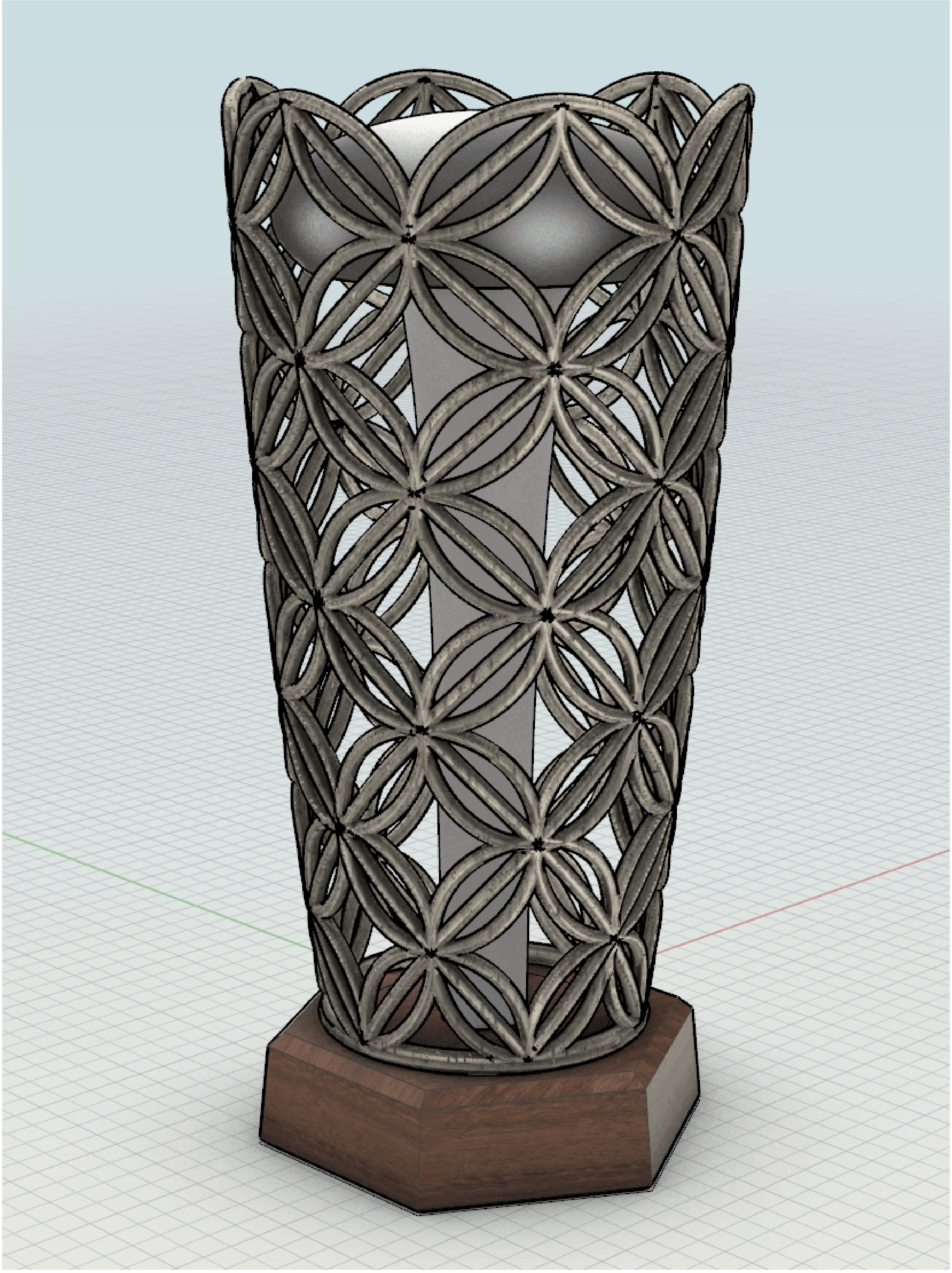


A side view of the robotic simulation shows the coordinated relationship between the extruder and rotating form as the pattern travels around the surface.

By combining a rotating substrate with continuous extrusion and computationally generated patterning, the process expands ceramic additive manufacturing beyond the familiar logic of layer-by-layer deposition.

Detail of a finished ceramic prototype, where intersecting extruded paths form a self-supporting floral lattice around the vessel.

Rhino provides the geometric foundation, Grasshopper transforms simple curves into continuous surface patterns, and Python bridges those geometries with the synchronized movement of the robot and rotary axis.



A Rhino visualization explores how the printed ceramic lattice could move beyond test pieces and become part of functional objects such as lighting.

The finished pieces make that computational logic visible. Their open lattices are not simply decorative skins applied after fabrication; they are the direct physical trace of a coordinated digital and robotic process.

A series of fired ceramic prototypes demonstrates the range of open lattice geometries achievable through the rotary extrusion process.

CREDITS

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