wavePavilion is an architectural installation generated by computer algorithms and built using custom digital fabrication technology. Completed in June 2010, the project is located on the grounds of the University of Michigan Taubman College of Architecture and Urban Planning, where it has a footprint of 20 x 30 feet, stands 14 feet tall, and contains over a kilometer of 1/4-inch diameter steel rod.

Consultants: Wes McGee (matter design studio) and Dave Pigram (supermanoeuvre).

Concept
Since the Renaissance, traditions of drawing have remained central to the discipline of architecture, contingent on a belief in the ability of the architectural line to represent space. In recent decades, however, computer modeling has largely supplanted the power of line with that of surface, particularly in the description of three-dimensional form. The dominance of surface is especially apparent in the still-nascent domain of digital fabrication. Digital fabrication has emerged as a way to build complex form through the use of computer-controlled machines to accurately produce non-standard parts. wavePavilion bucks this trend, challenging the contemporary focus on surface by harnessing the potential of algorithmic computing to re-empower the line as a driver of architectural form. Materially, this translates to the replacement of surfacial, sheet materials such as plywood, metals, and plastics, with extruded steel rod—a material reflecting a line-driven formal order.

Digital fabrication has the potential to collapse the longstanding divide between the architect’s act of representation and the builder’s act of construction. As the relationship between idea and outcome becomes more fluid, the scope of architectural practice might be expanded by the development of tools that reinforce design intent. As the architect becomes invested in methods of production, material properties and fabrication strategies emerge as key drivers of design. To this end, wavePavilion emphasizes the development of tools and processes in tandem with the development of ideas and form as a means of maintaining an architect’s authorship amid an increasingly mechanized fabrication process.

Computational Design
The structure and aesthetic of wavePavilion was designed through a rule-based strategy of geometric evolution. As the Pavilion form constricts the lengths of the components diminish and the structural pattern evolves into an aesthetic gesture.
programmed set of rules, a *script*, combined functional influences with the intrinsic formal tendencies of linear geometry to produce an architectural space. This computational process can be described in a series of phases, as seen in the adjacent diagrams.

The virtual environment in which this computational process operates is established in a 3D modeling software. This environment is seeded with information tied to real-world spatial requirements. This information influences the behavior of the script as it grows within the environment, demarcating two zones with distinct views and orientation [Figure 1]. These spaces are simultaneously connected and autonomous, a perception reinforced by the modulating density of the emerging form. A secondary array of geometry delaminates from the primary form, highlighting the internal variation possible within a single form-making strategy.

A network of three-dimensional lines grows from the base geometry on the ground plane [Figure 2]. Each segment develops with a specific scale and direction with respect to the formal tendencies of the script and the real-world information embedded in the environment. These lines are the progenitors from which more complex geometry evolves. This *ancestor geometry* establishes the morphological characteristics of the pavilion, but lacks the sophistication to address issues of structural integrity and user occupation.

The *descendent geometry* [Figure 3] refines the *ancestor geometry* through new rules based on proximity to neighboring lines. Individual components engage in physical exchange with their neighbors, forming aesthetic and structural alliances toward the development of a cohesive *society of form*. This *form society* displays broad networks of structural affiliation while maintaining a high degree of local diversity [Figure 4]. Behavioral gradients read across the breadth of the pavilion, but moments of eccentricity—phase shifts, vestigial phenotypes, dormant features—reveals the complex relational processes of the underlying system. Through this process of formal evolution, *wavePavilion* manifests an index of its own phylogeny while satisfying pragmatic requirements of built, occupiable form.

**Robotic Fabrication**
The project relies on precise fabrication and assembly of its constituent elements. To this end, a multi-use 7-axis robotic arm was paired with a bespoke CNC rod-bending device [Figure 5]. These operated in tandem to shape multi-planar...
Robotic Fabrication

A custom CNC rod-bending device operates in tandem with a multi-use 7-axis robotic arm to shape the steel components. The behavior of this toolset is driven by a communication script which translates 3D computer geometry into robot/bender choreography.
components out of 1/4-inch steel rod. A custom script was developed to analyze the digital geometry and translate that information into a series of operations for the bender and robot. The data is exported as a series of commands which direct the actions of the robot and bender in order to construct the digital geometry out of steel rod [Figure 6].

The bent components were organized with an indexing system and transported to the site, where they were manually assembled. The non-standard nature of each component is ultimately beneficial as it eliminates the need for positioning jigs: each component can only align with its neighbors in a single, specific orientation.

**Conclusion and Projection**

*wavePavilion* was a quick, two-month investigation that has since initiated an ongoing trajectory of research. Both scripting and customized robotic fabrication have a daunting learning curve that inhibits the potential of these tools and processes, so the physical and computational tools developed for *wavePavilion* have been shared with other designers in hope of accelerating the research through open-source participation. Experimentation by the authors and others have continued in 1/4-inch and 3/8-inch metal rod. Refinements to the toolset are also ongoing, and the next-generation bending device currently in development will expand this experimentation to larger diameter materials. Computational improvements, such as visualization software to better predict fabrication challenges, expands both the operability of these processes and their capacity for broader application. Mechanical attachments might replace welded connections to increase assembly speed. Secondary membrane systems may be developed to provide enveloping capacities. The bent steel of *wavePavilion* may even be paired with wire mesh and shotcrete to produce highly customizable structural forms. Perhaps most critical of all, *wavePavilion* is a proof-of-concept showing the potential of digital fabrication and its ability to link conception and production without the need for the mediation that occurs between design intent and fabrication in conventional construction.