Inventioneering Architecture

building a doubly curved section through Switzerland

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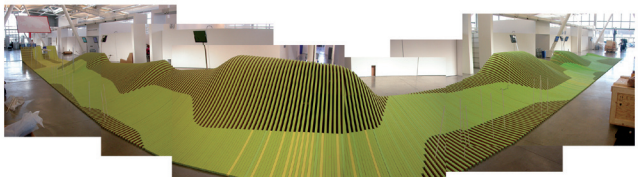
Inventioneering Architecture –

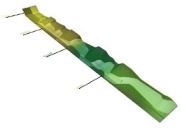
building a doubly curved section through Switzerland



The 1000 rafters of "Inventioneering Architecture" at the CCA San Francisco (Image: Instant Architects)

An automated digital process chain:

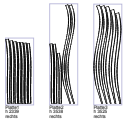
1) Defining the Geometry



The first script imports the original design defined as a NURBS-surface from the modeling software Maya, reads the coordinates of the platform's cross-sections for every rafter and determines the angles of bank.

Language: MEL (Maya)
Output: Curve geometry in XML

2) Detailing and Nesting



After defining the exact geometry of the structure, this "abstract" description has to be translated into detailed geometries for the single parts. A second script adds to the surface geometry the complete geometry for all 1000 rafters, including all drillings for the connecting wood dowels. A third script arranges the rafters on the MDF-boards to minimize waste and optimize cost.

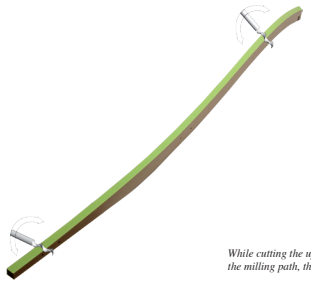
Language: VectorScript (VectorWorks)
Input: Curve geometry XML
Output: machine code for the router

3) G-Code Generation

```
N250  X88.547 Y428.722
N252  X88.547 Y481.983
N254  X272.250 Y481.983
N256  X272.250 Y428.722
N258  X272.250 Y1079.428
N260  X272.250 Y1132.689
N262  X88.547 Y1132.689
N264  X88.547 Y1079.428
N266  X272.250 Y1556.798
```

A final script is created which generates the appropriate code for all MDF-boards from the CAD-model of the nested rafters. Those codes are then handed back to the manufacturer and fed directly into the five-axis-router to start roughly 50 milling hours of production.

Language: machine code / G-Code
Output: production router



While cutting the upper surface of the rafter, the milling tool rotates around the milling path, thus creating a doubly-curved surface in one go.

"Inventioneering Architecture" is a travelling exhibition of the four Swiss architecture schools (Zurich, Lausanne, Geneva and Mendrisio) that was first shown at the California College for Arts and Crafts (CCAC) in San Francisco and is now touring the world. For this project the office Instant Architects in Zurich designed a stage, which resembles an abstract crosscut through Swiss topography. This doubly curved platform measures 40 by 3 metres with varying heights up to 1.5 metres. A footpath meanders along the surface, passing the exhibits.

In order to meet the budget requirements, the authors proposed to assemble the hilly platform from 1000 individually curved rafters that were milled out of 40mm medium density fibreboard (MDF). They are assembled in comb-shape, so that their overlapping sections form the closed surface of the path while the exhibition area is marked by gaps. By choosing a rather cheap material and implementing a continuous digital chain from the definition of the surface geometry in the CAD software Maya until the control of the five-axis CNC-mill that the parts are manufactured with, production costs could be lowered significantly.

The detailing was developed closely after the capabilities of a five-axis router. The platform is divided into 40 millimetre wide cross sections, each describing the upper surface path of one rafter. The milling tool follows this path and rotates around it at the same time, cutting out a so called "ruled surface" that follows the topography of the platform both along and across the section. Thus it is possible to manufacture a three-dimensional, doubly curved surface from two-dimensional sheet material at very low cost. The rafters are connected by dowels and supported by perpendicular boards.

Since the structure consists of roughly 1100 individually shaped parts, the crucial point was to automate the translation of the platform geometry into the geometry of the single parts and finally into the steering code (G-Code) for the computer controlled mill.

"Inventioneering Architecture" is a traveling exhibition of the four Swiss architecture schools that was touring the world during 2005/06. This doubly curved exhibition platform resembling an abstract crosscut through Swiss topography measures 40 by 3 meters. The authors proposed to assemble the hilly platform from 1000 individually curved rafters that were milled out of 40mm medium density fiberboard (MDF). By implementing a continuous digital chain from the definition of the surface geometry in the CAD software Maya until the control of the five-axis CNC-mill that the parts are manufactured with, production costs could be lowered significantly. The detailing was developed closely after the capabilities of a five-axis router. The platform is divided into 40 mm wide cross sections, each describing the upper surface path of one rafter. The milling tool follows this path and rotates around it at the same time, cutting out a so called "ruled surface" that follows the topography of the platform both along and across the section. In order to meet the budget requirements, the crucial point was to automate the translation of the platform geometry into the geometry of the single parts and finally into the steering code (G-Code) for the computer controlled mill.

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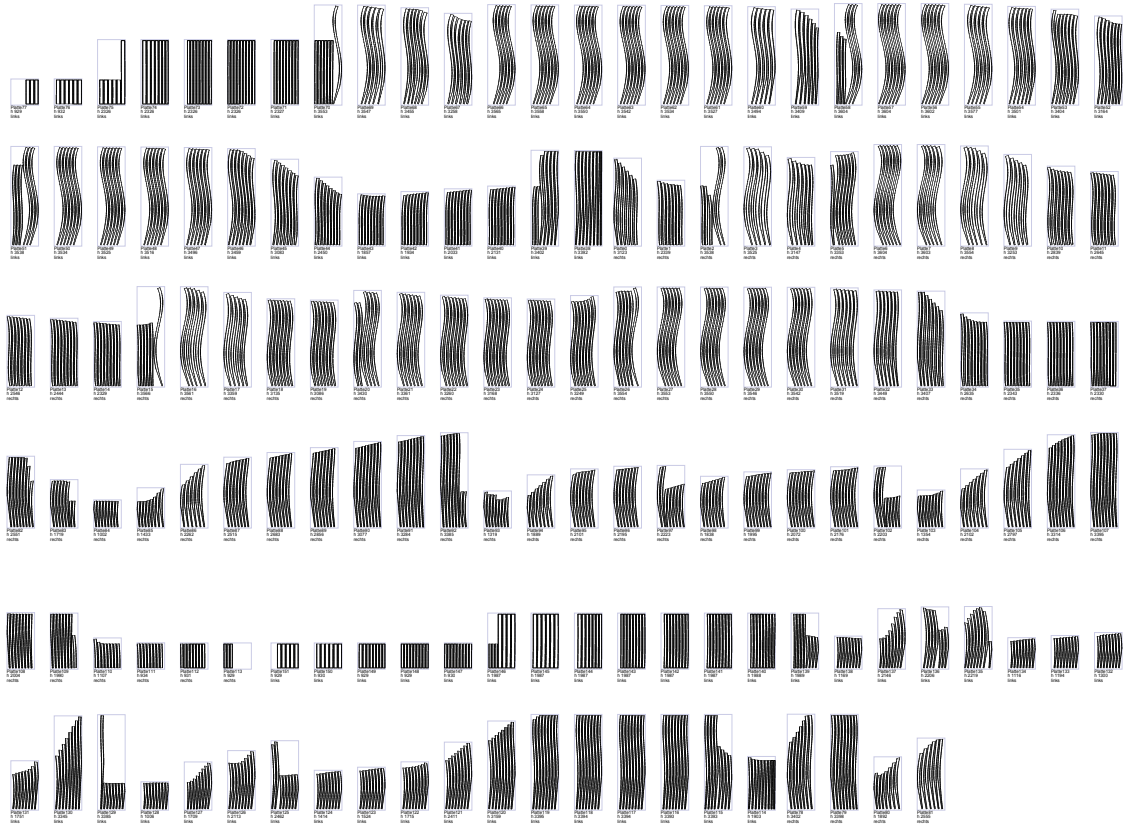

The platform's 1100 rafters are automatically nested and optimized on 152 MDF-boards. One G-Code per board is generated for the 5-axis router. The rafters are defined by Spline-curves, but since the CNC-router only uses straight lines and radii, the curvature had to be approximated by polygons with a point distance of 9.0 mm.

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