The

Framed

Pavilion

The Framed Pavilion

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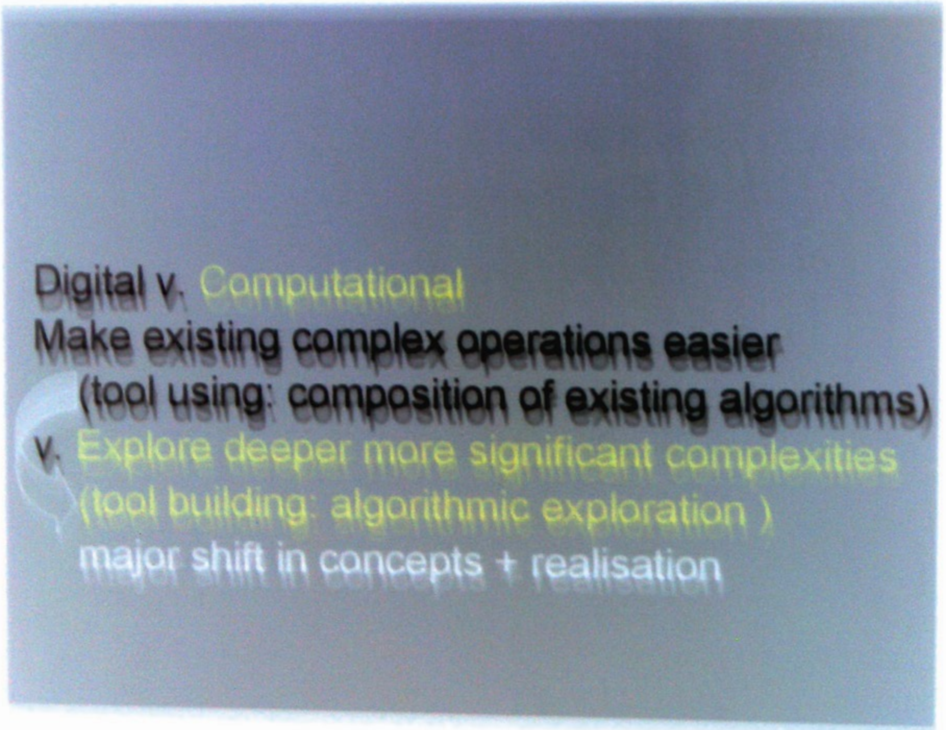
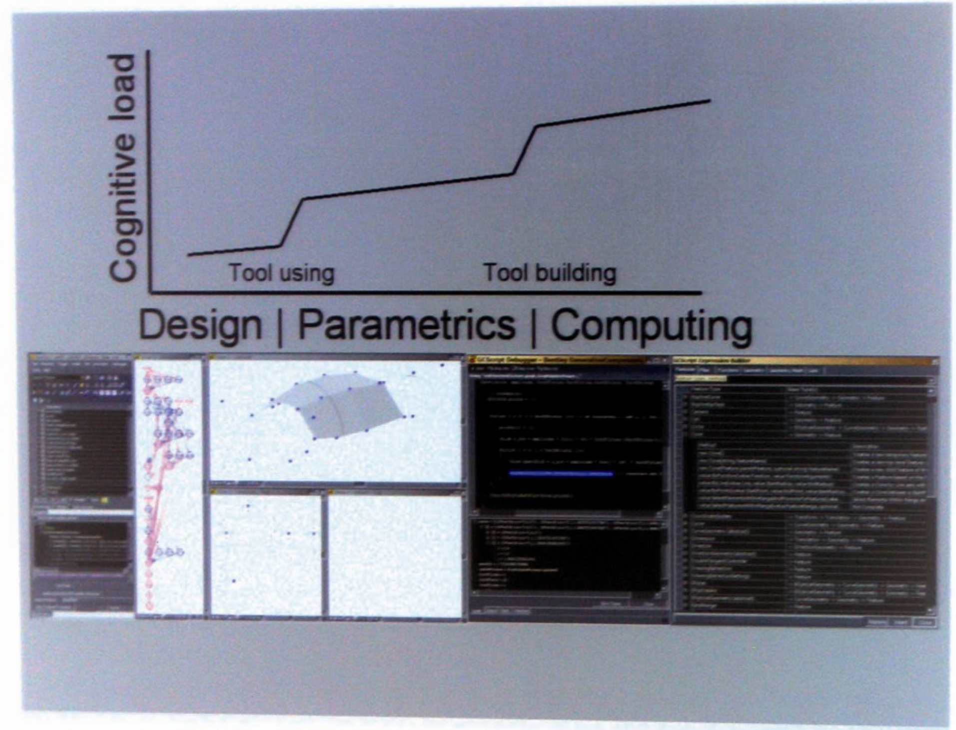
Institute of Architecture and Media
Graz University of Technology

Modelling and Producing
Complex Systems
in Architectural Education

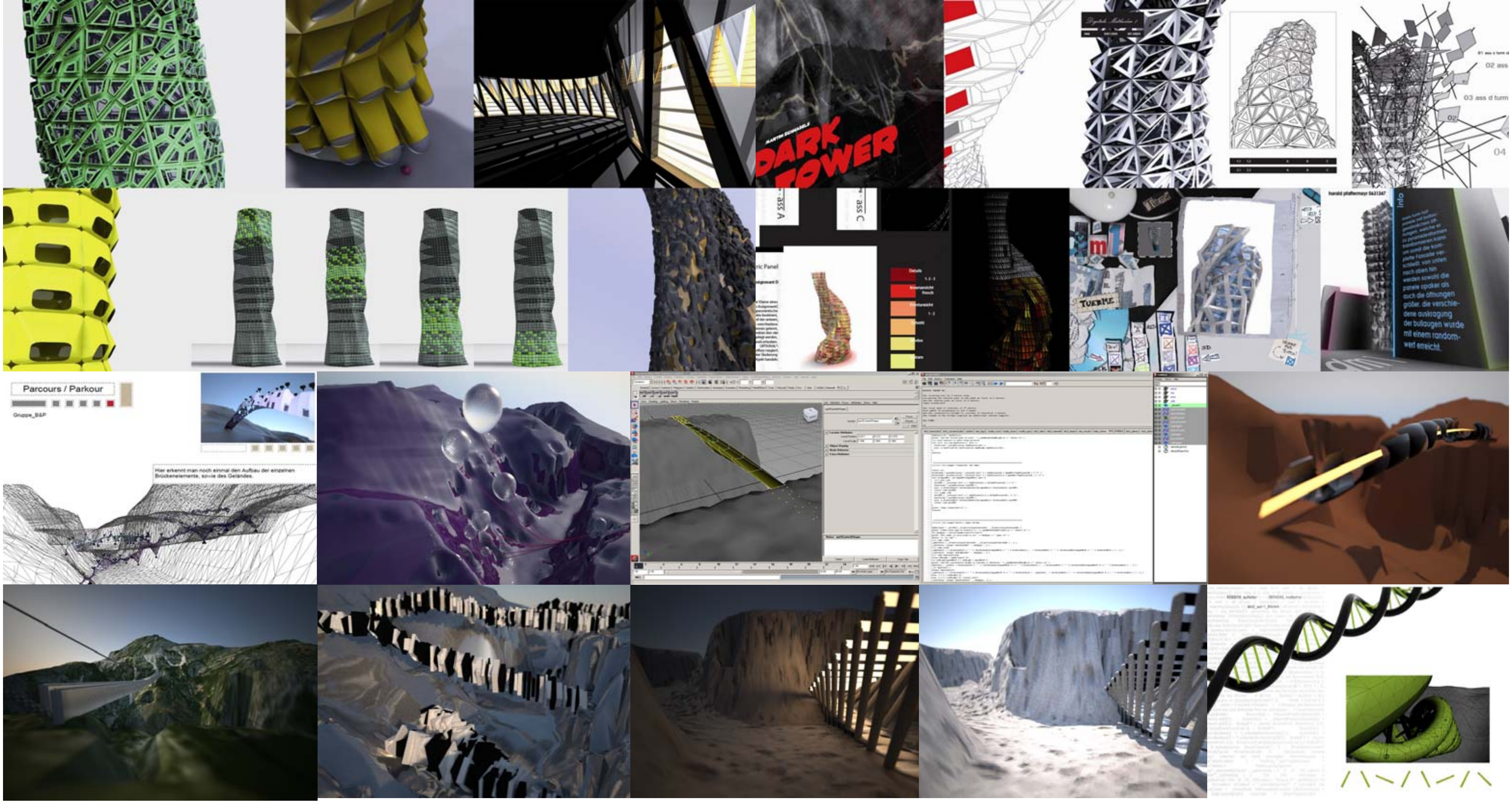
The Framed Pavilion





Code: the Ultimate Way to Control

As a consequence this means that future architects must be trained in designing the “aesthetic surface” as well as **being able to formalize the process**. They need to be programmers (to a certain extend) and know CNC technology with all its constraining and liberating features, so that there is no necessity to “dissect the frog”. The designer should be able to “build it” from scratch.



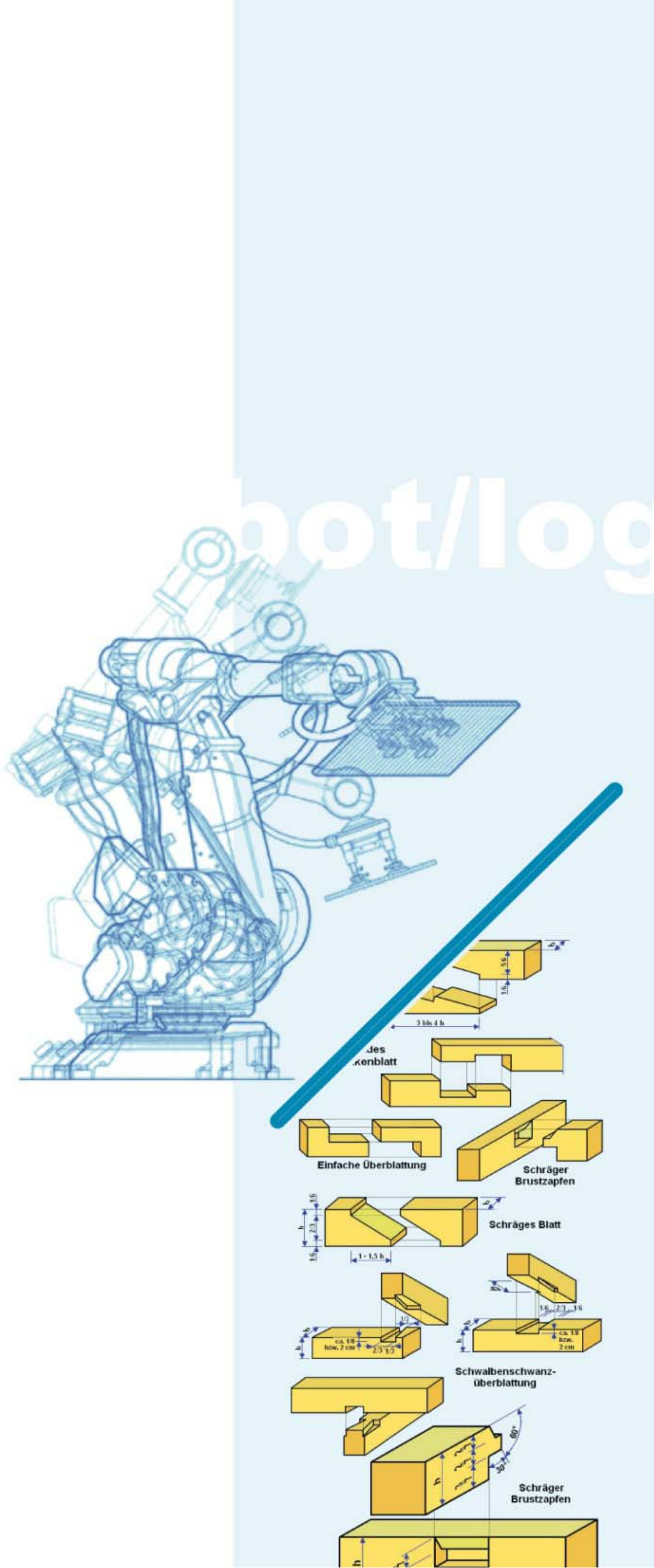
In the end of each course second year students (and higher) should **have developed their own "digital tools"** - as we call them - for the realization of their projects. They need to originate their own applications. No preconceived strategies are desired - no predefined output is allowed. **Students must design the process and not the result.**

Code: the Ultimate Way to Control

Robots: the Ultimate CNC Machines

In contrast to this, the scientific approach of the Institute of Architecture and Media is not necessarily based on a problem. **We try to take a given tool and explore its capabilities.**

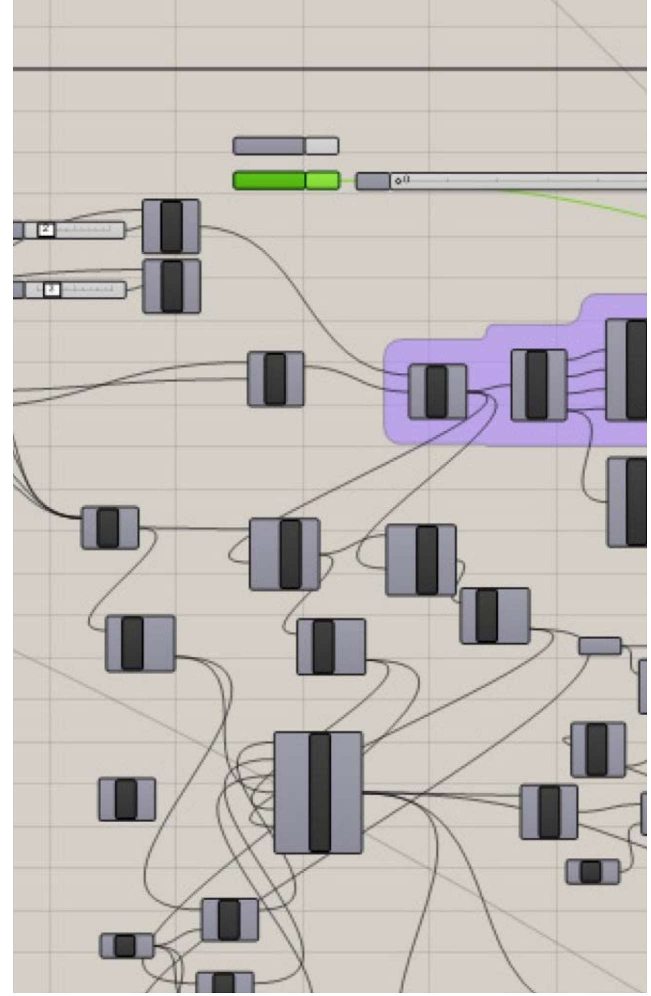
Our goal is to get to the bottom of that tool, discover the present limits of its employment and expand the borders of what is possible. And, as we are currently working at the university, we always feel the **need to focus on the process, the research and the education of future architects** rather than on the pure result.



Parametrics/Joints
constructed/designed
by/in
Robots/Wood

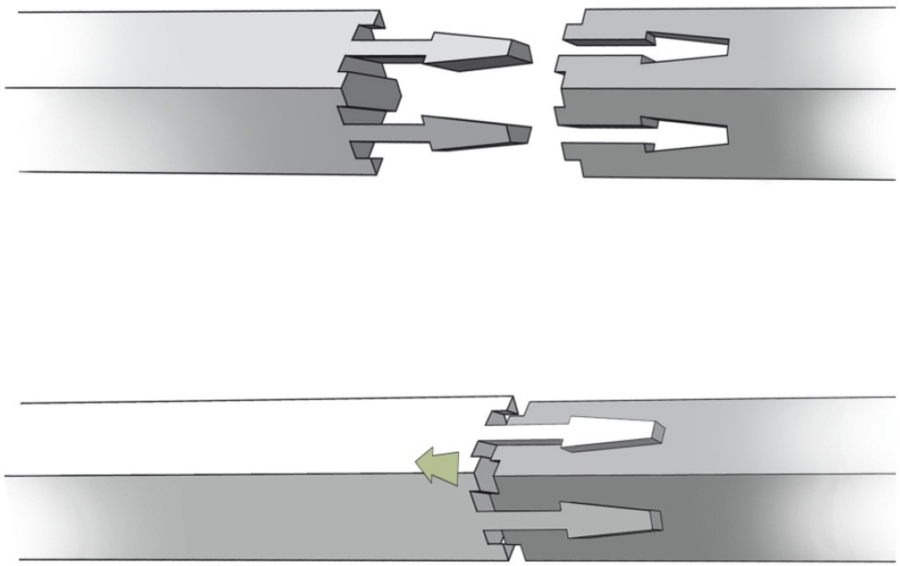
Master/Designstudio
Winter 2011/12

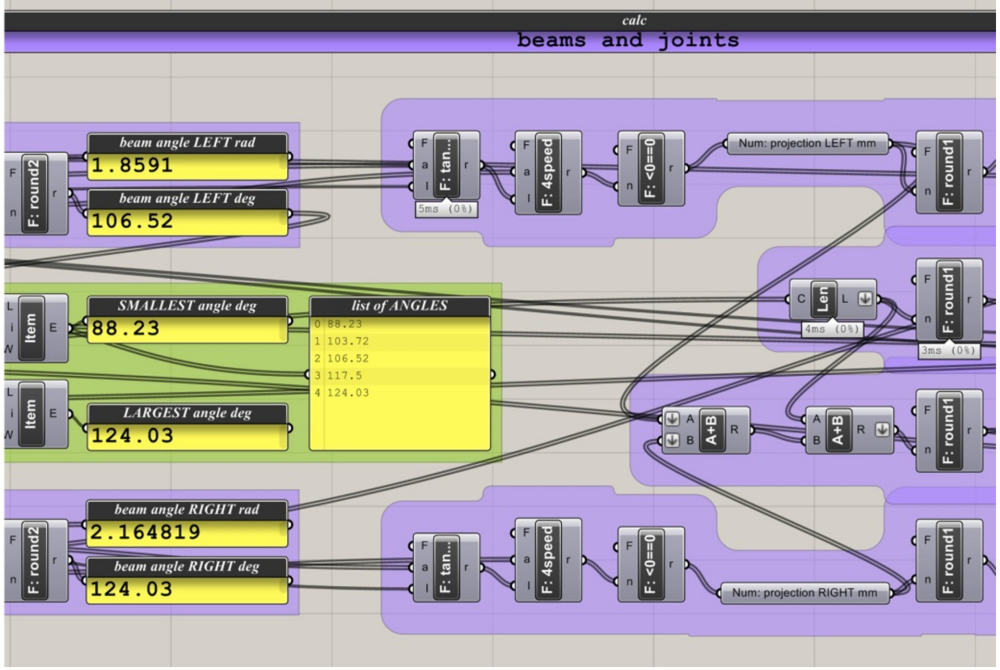
bot/log



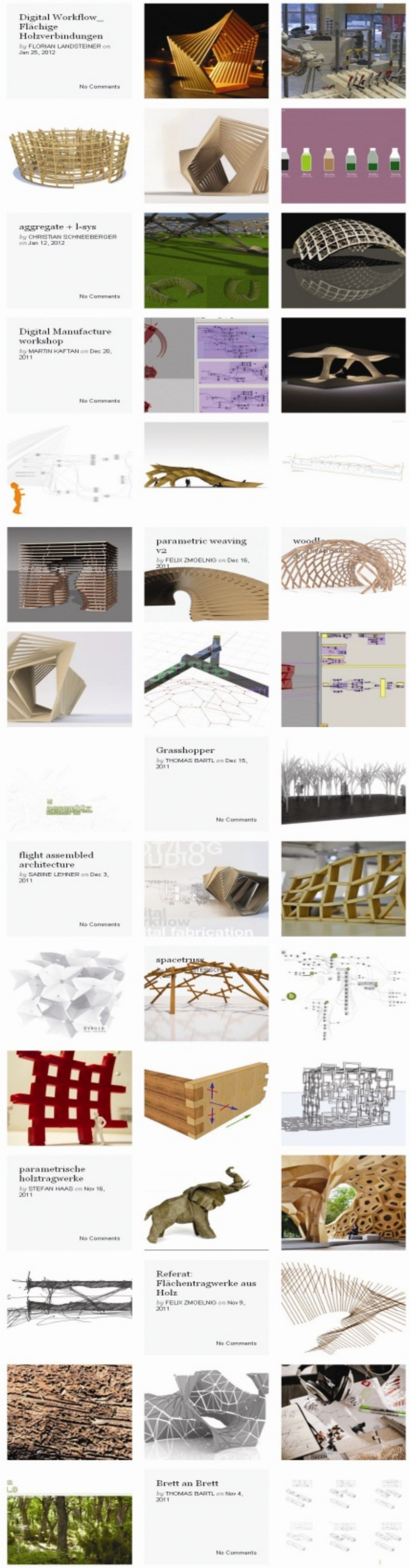
The Objective: Design a structure and all joints **solely made from timber**, no glue or other fasteners or fixings allowed. For the realization **use the capabilities of a 6-axes robot** on an additional linear axis. Moreover **the entire project must be applied parametrically!**

bot/log



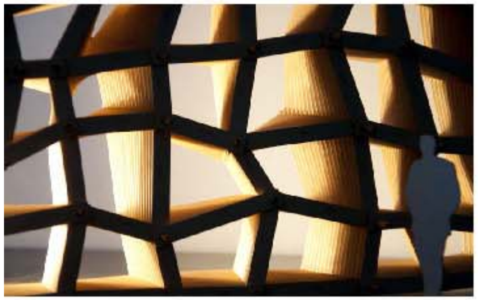
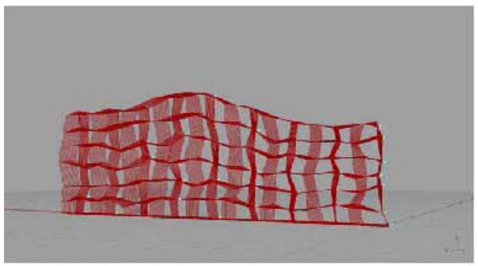


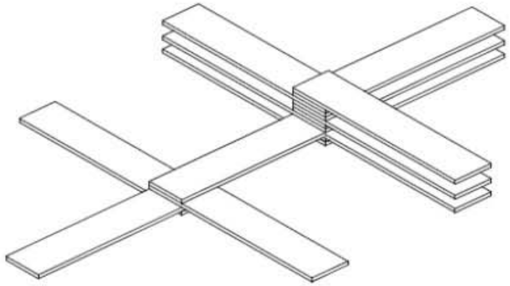
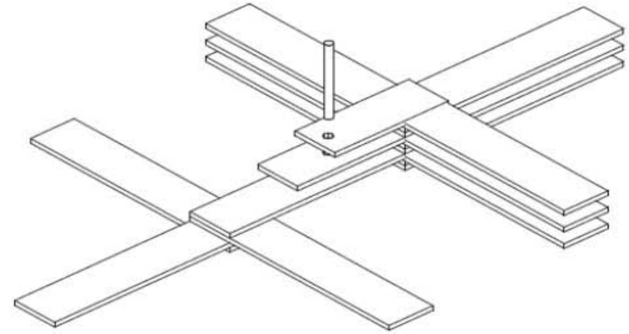
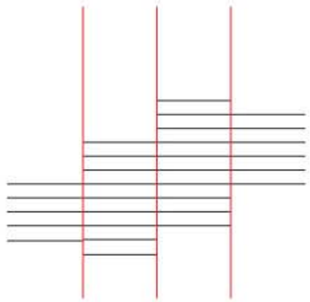
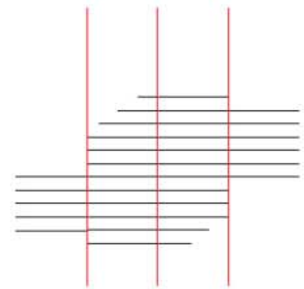
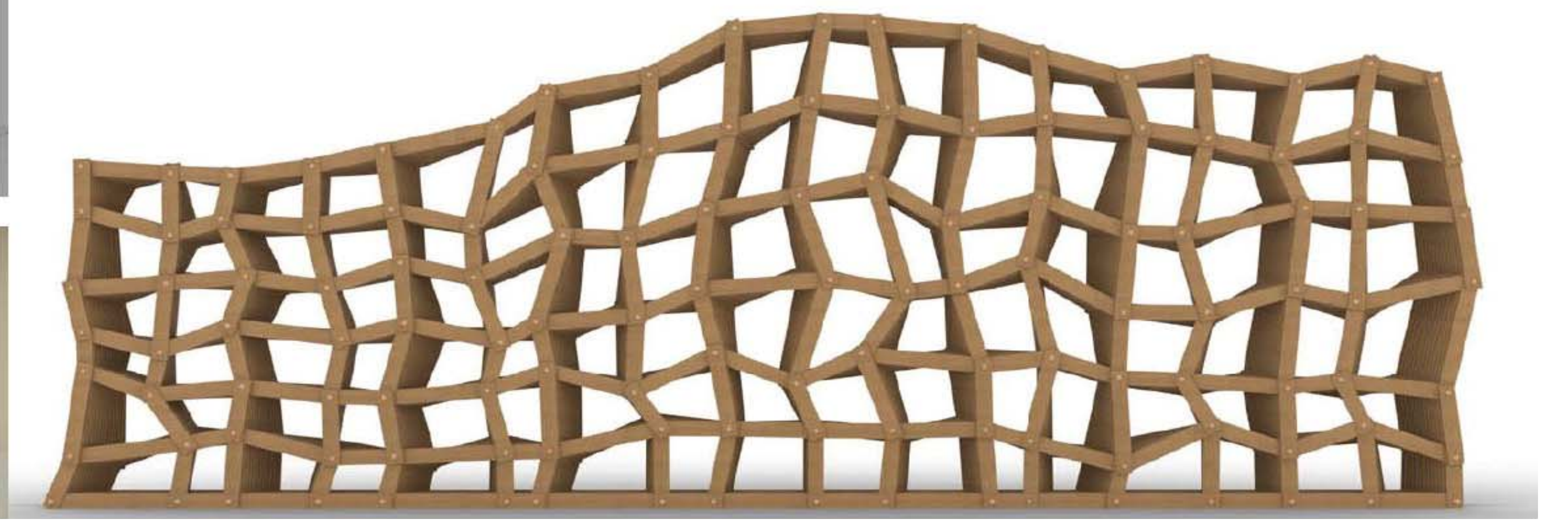
Start to **analyze existing and traditional wood joints** and test their possibilities to transform them to digital and parametrical models. Next step is to **improve the parametrical models in consideration of producing all joints with our robot** and the milling environment.



The Studio concluded with **18 individual full-scale algorithmic projects** and one completely implemented and built structure: **The Framed Pavilion** (TFP).

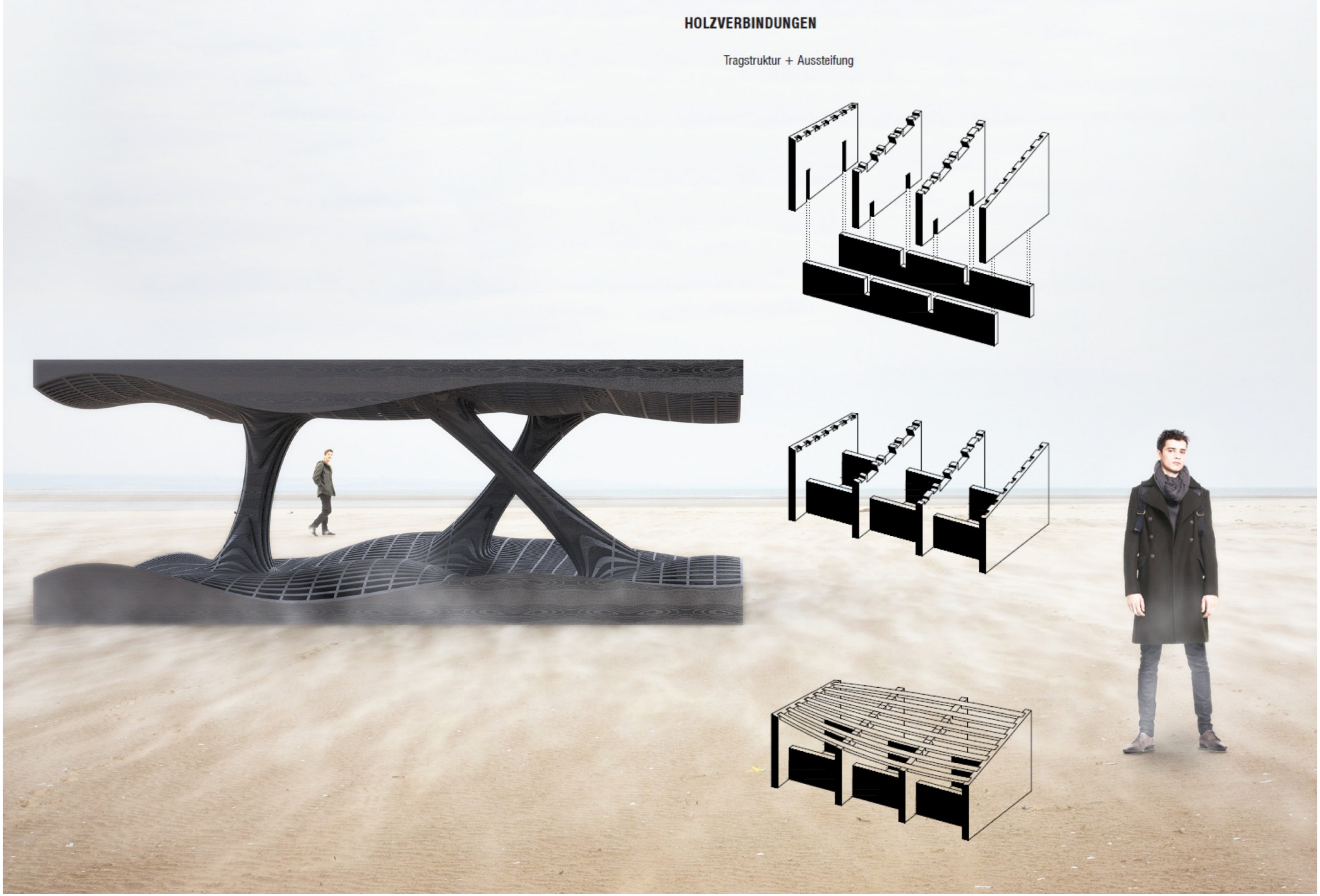
bot/log

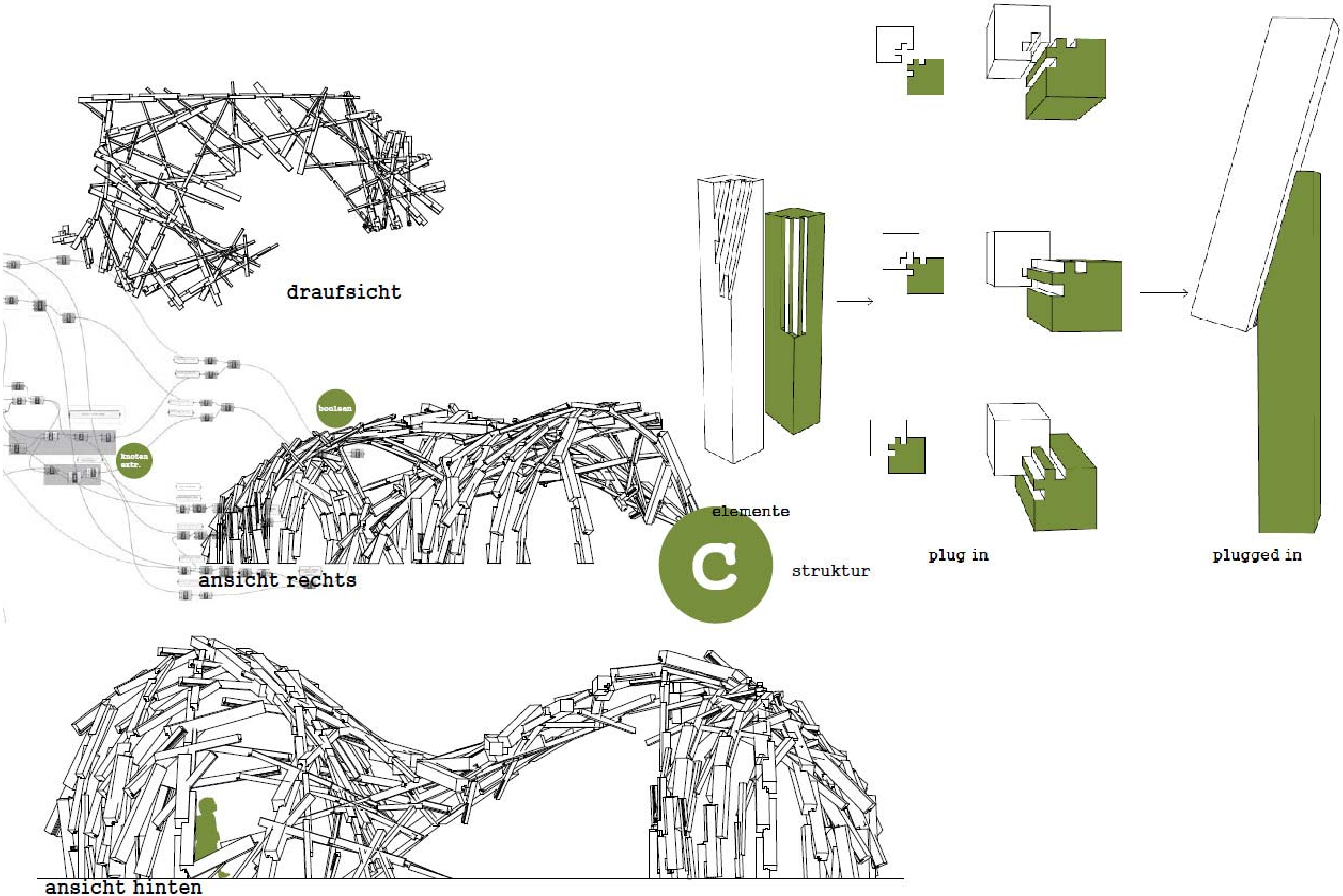
//// **3688** by Stefan Nuncic

bot/log



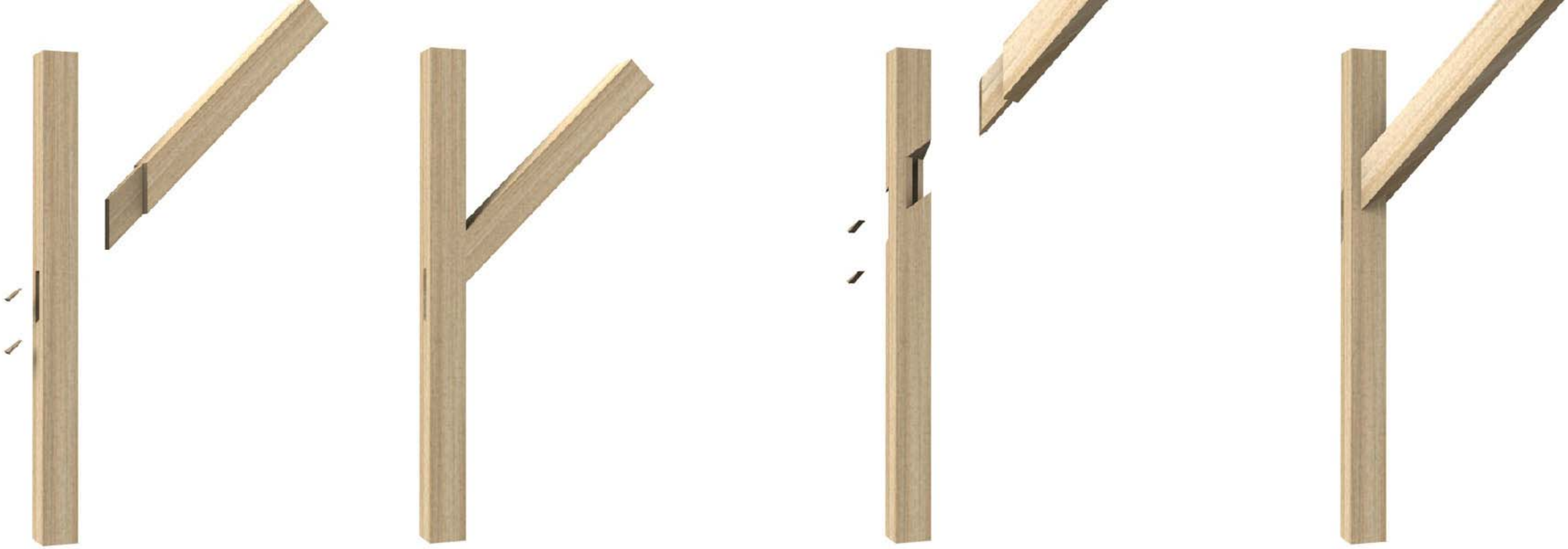
Holzspaltung by Stefan Jos

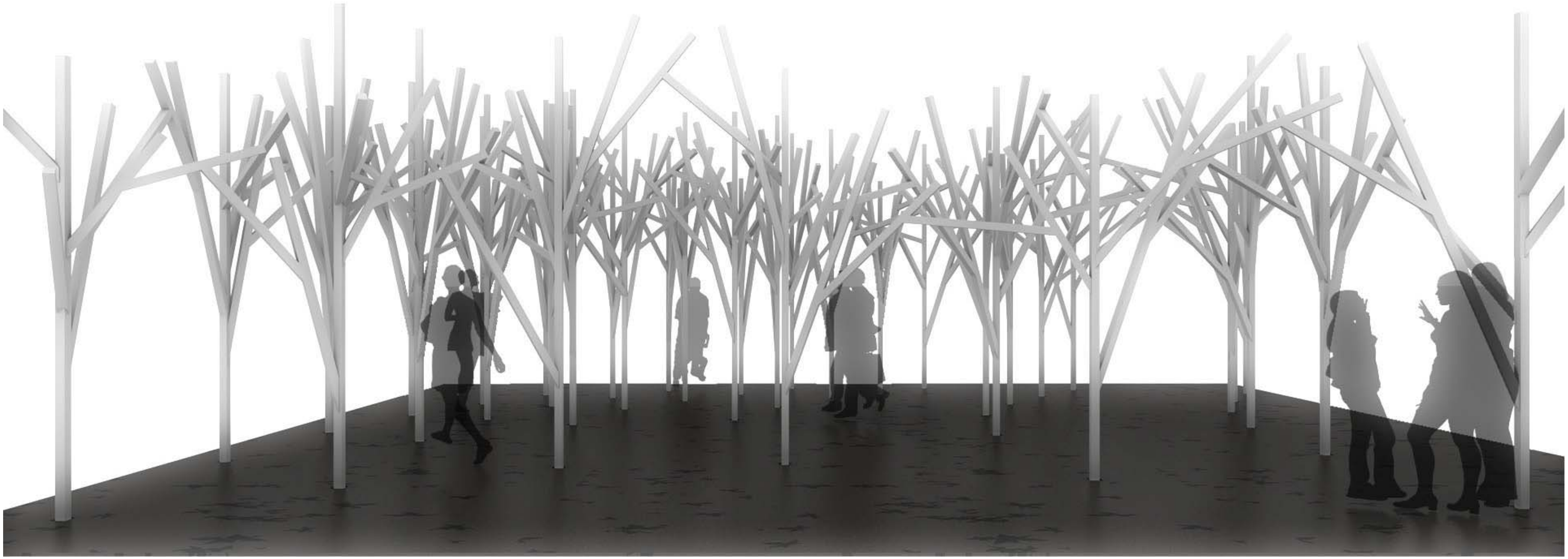
bot/log



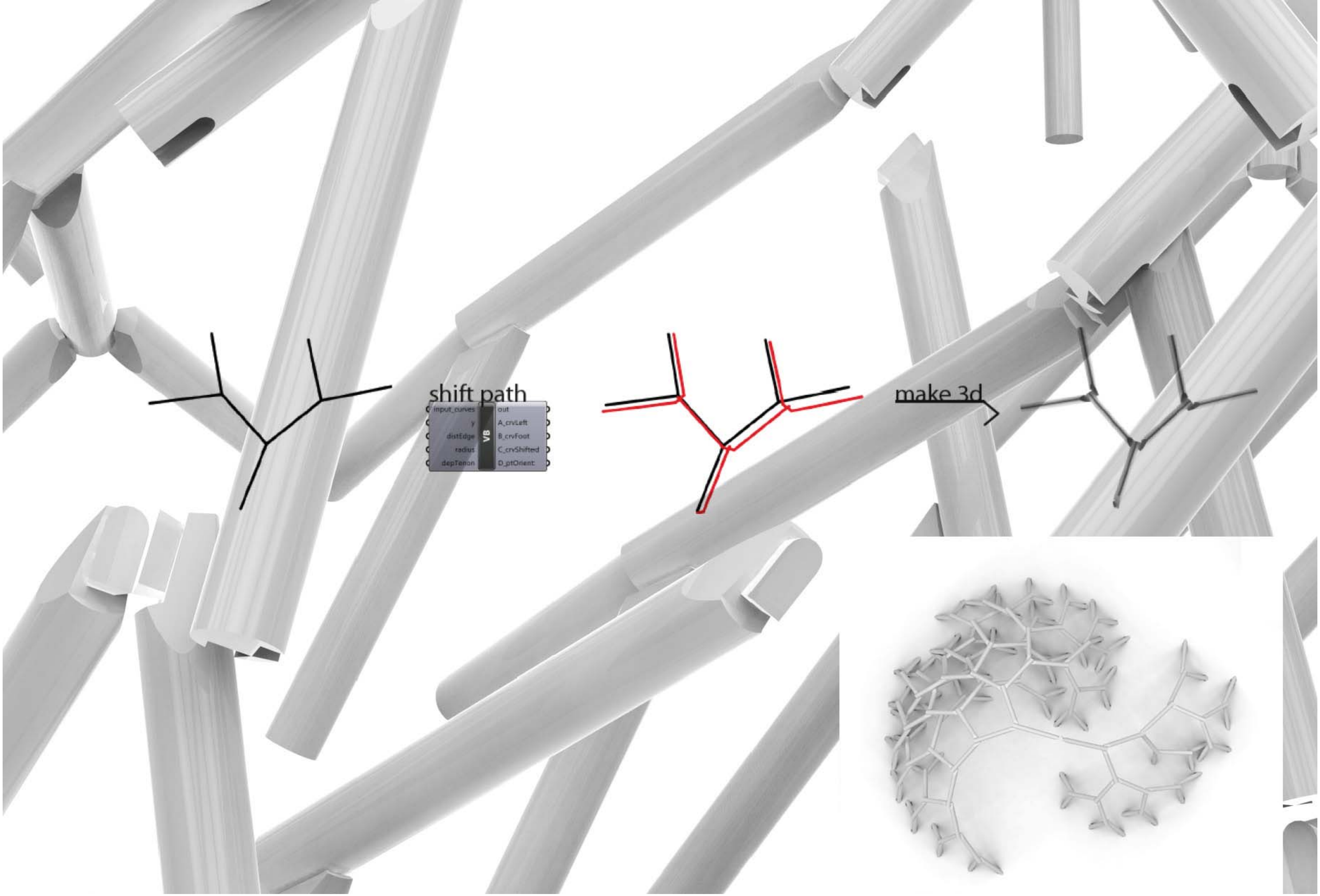
the wooden tree structure 3.0 by Sara Vidacak

bot/log

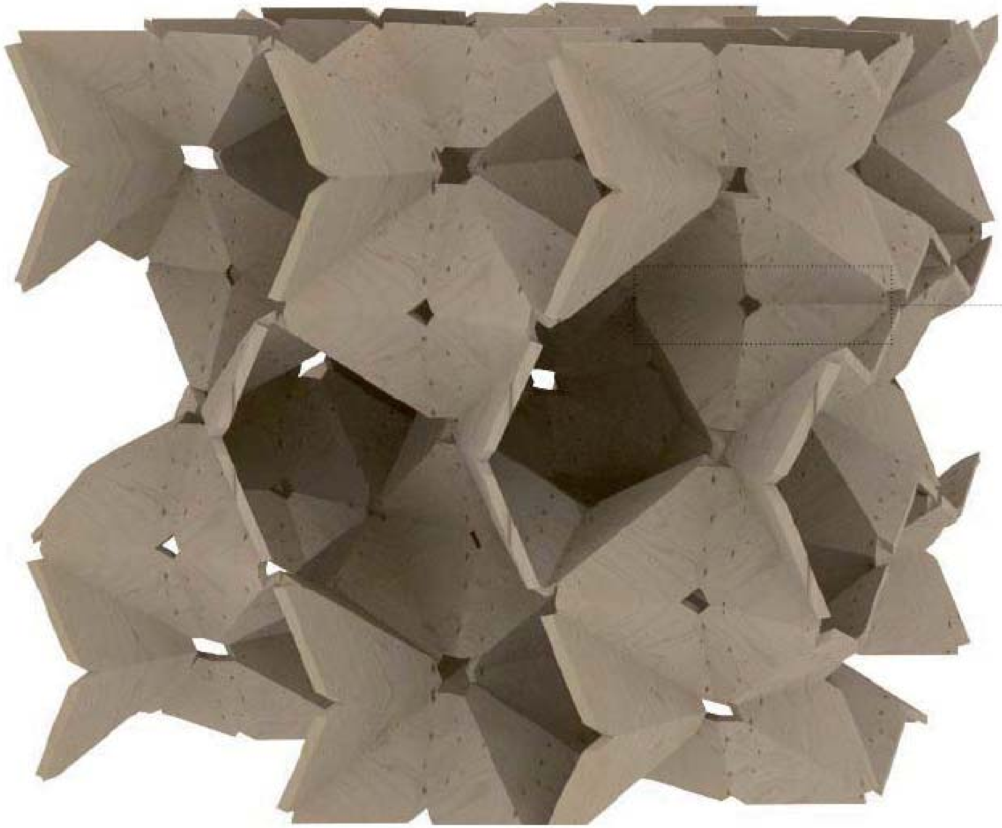




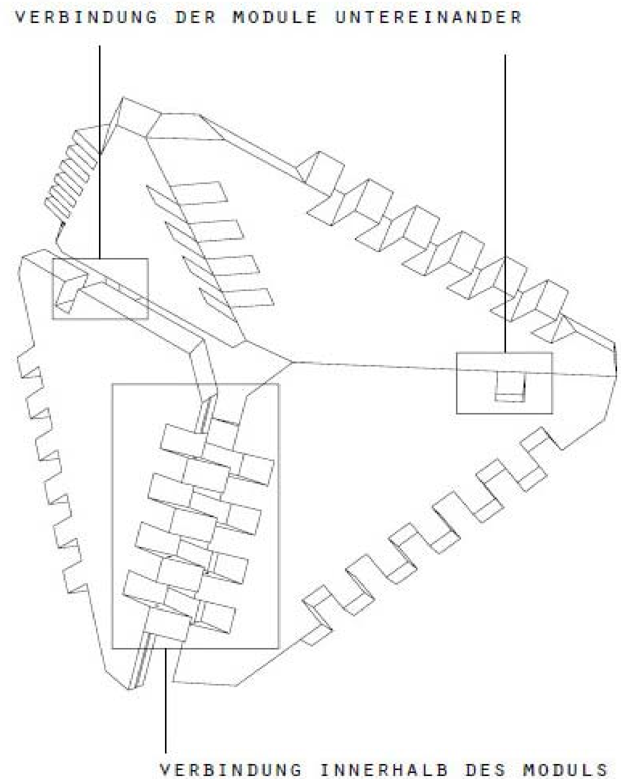
Parametric Joint by Karl Pansy



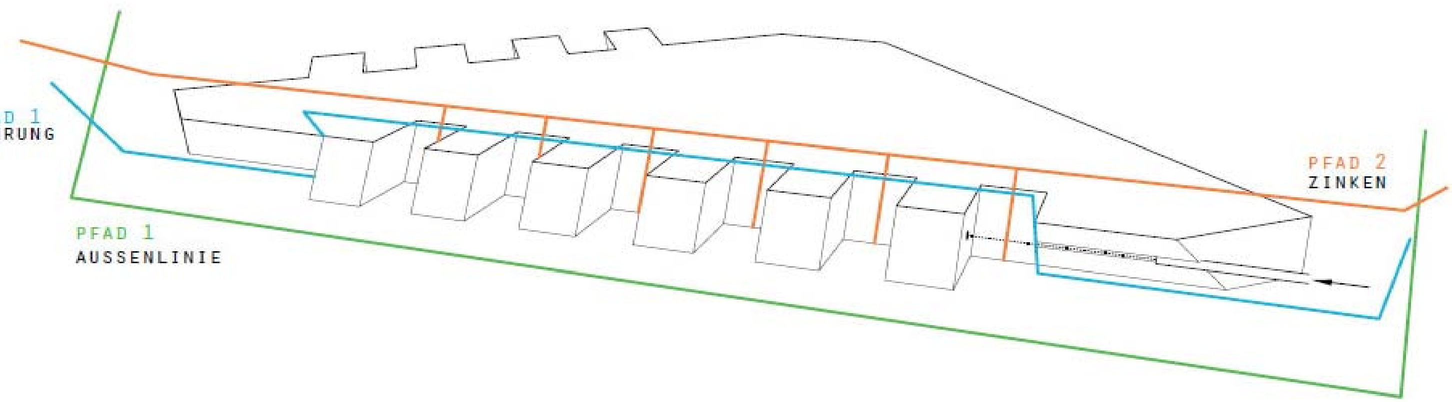
aggregate by Christian Schneeberger



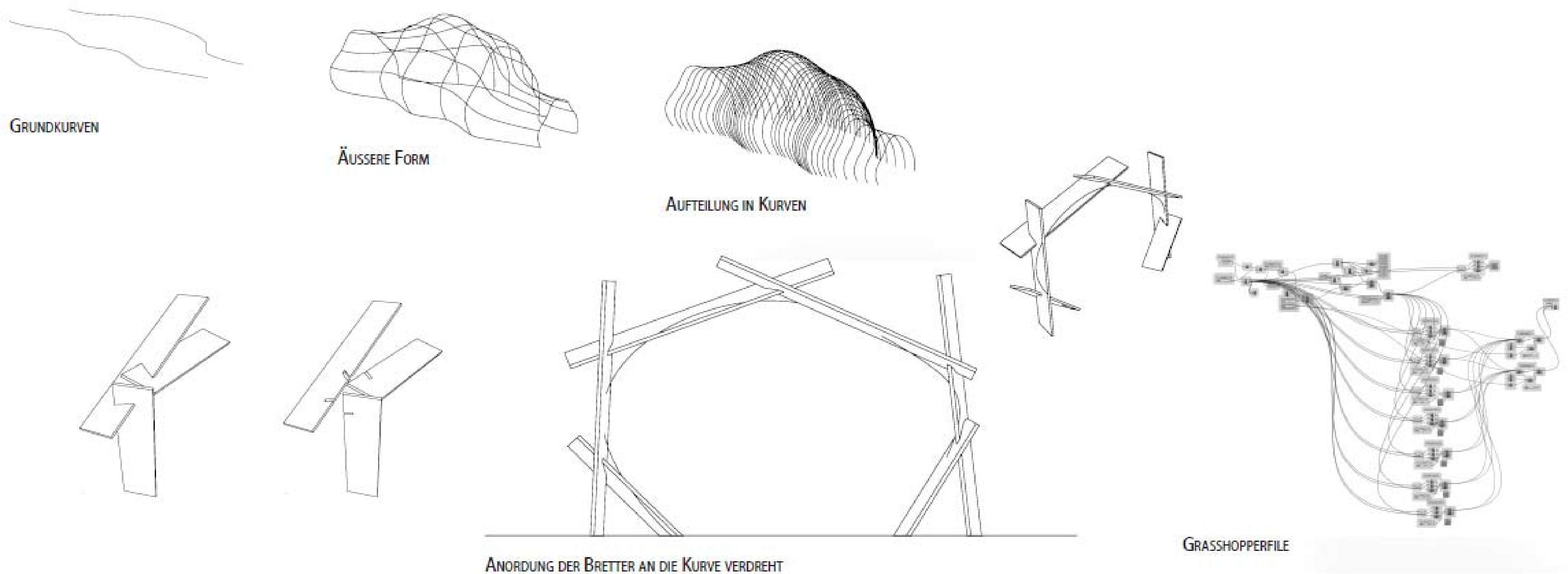
STRUKTUR NEU OHNE

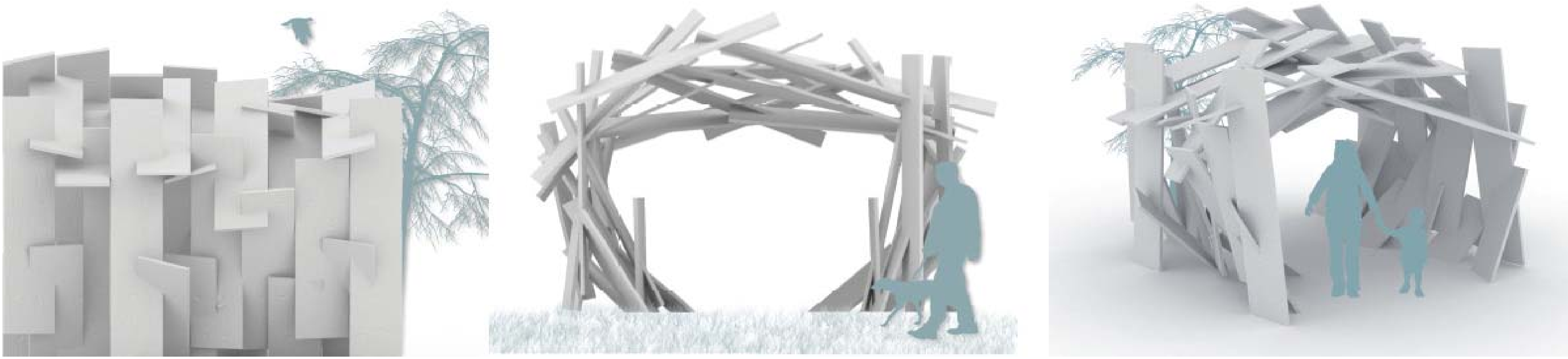


Verbindung



GYRO parametric by Georg Hansemann



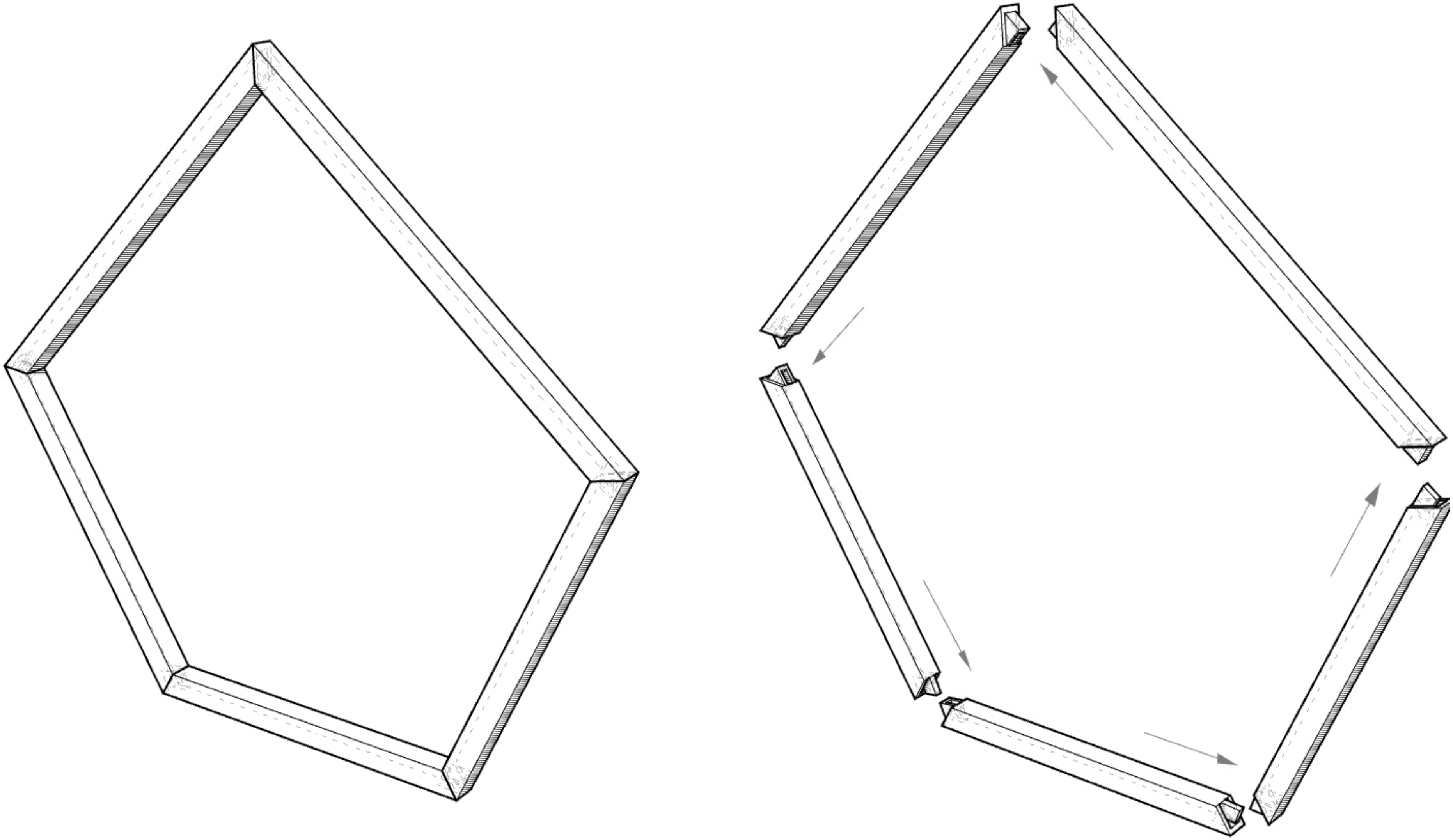


BretterHaufen by Thomas Bartl

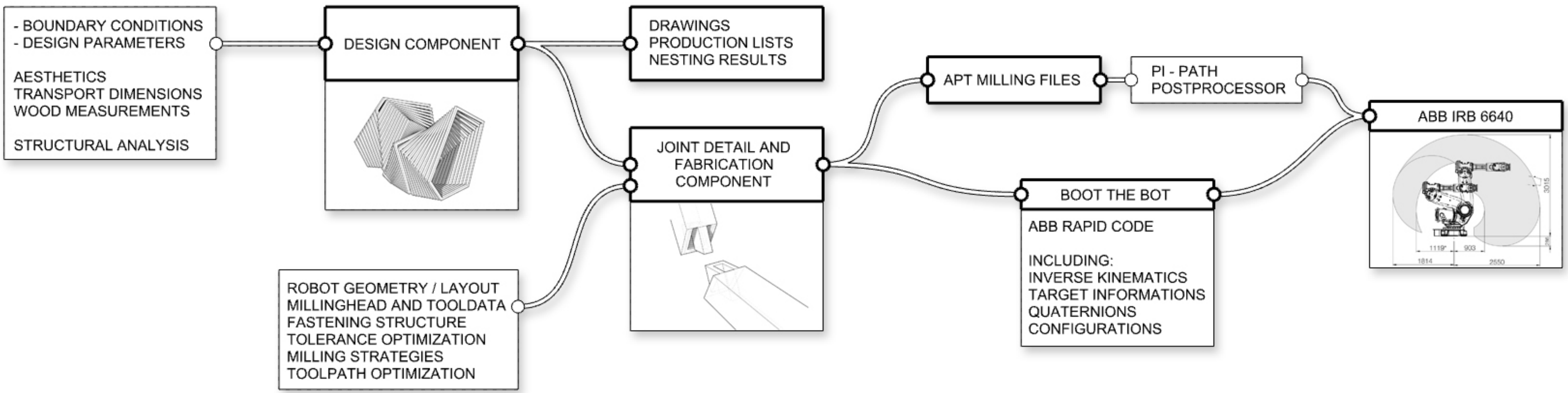
bot/log

The Framed Pavilion by Sabine Lehner

The Evolution of TFP



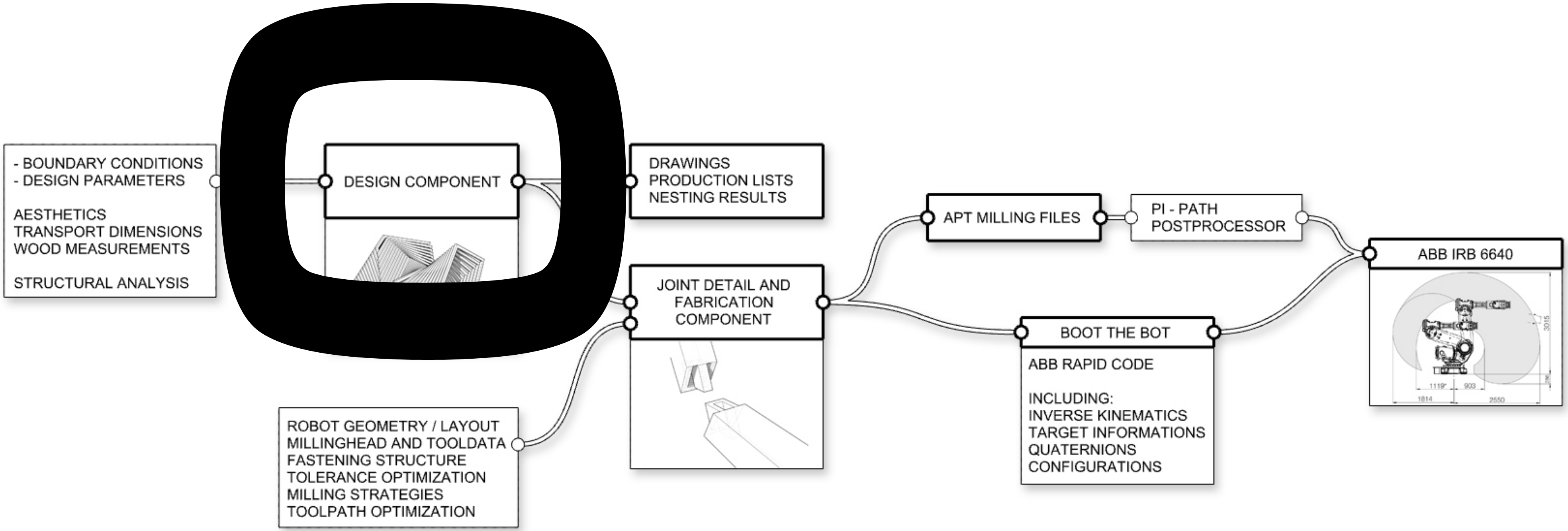
Sabine Lehner's original design intention of was to build **irregular pentagonal frames mutating along an axis**. The implemented algorithmic process enables the user to convert any basic surface that seems appealing.



The Framework for the conceived design to production workflow was Rhinoceros extended by its visual programming language **Grasshopper**.

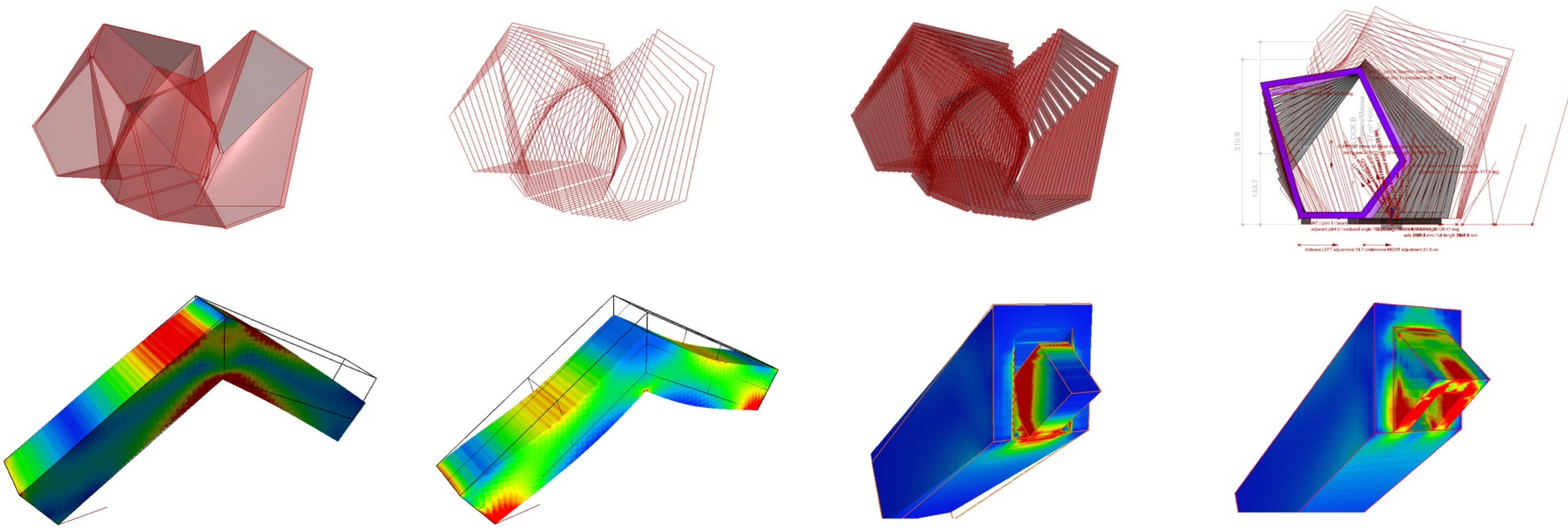
Due to performance and handling issues of large datasets we decided to split our parametrical process into two components that are linked together:

1. **Design Component**: Definition of boundary conditions and design environment for the main structure.
2. **Joint Detail and Fabrication Component**: Elaboration for the joint details with building and fabrication requirements including robot code generation.

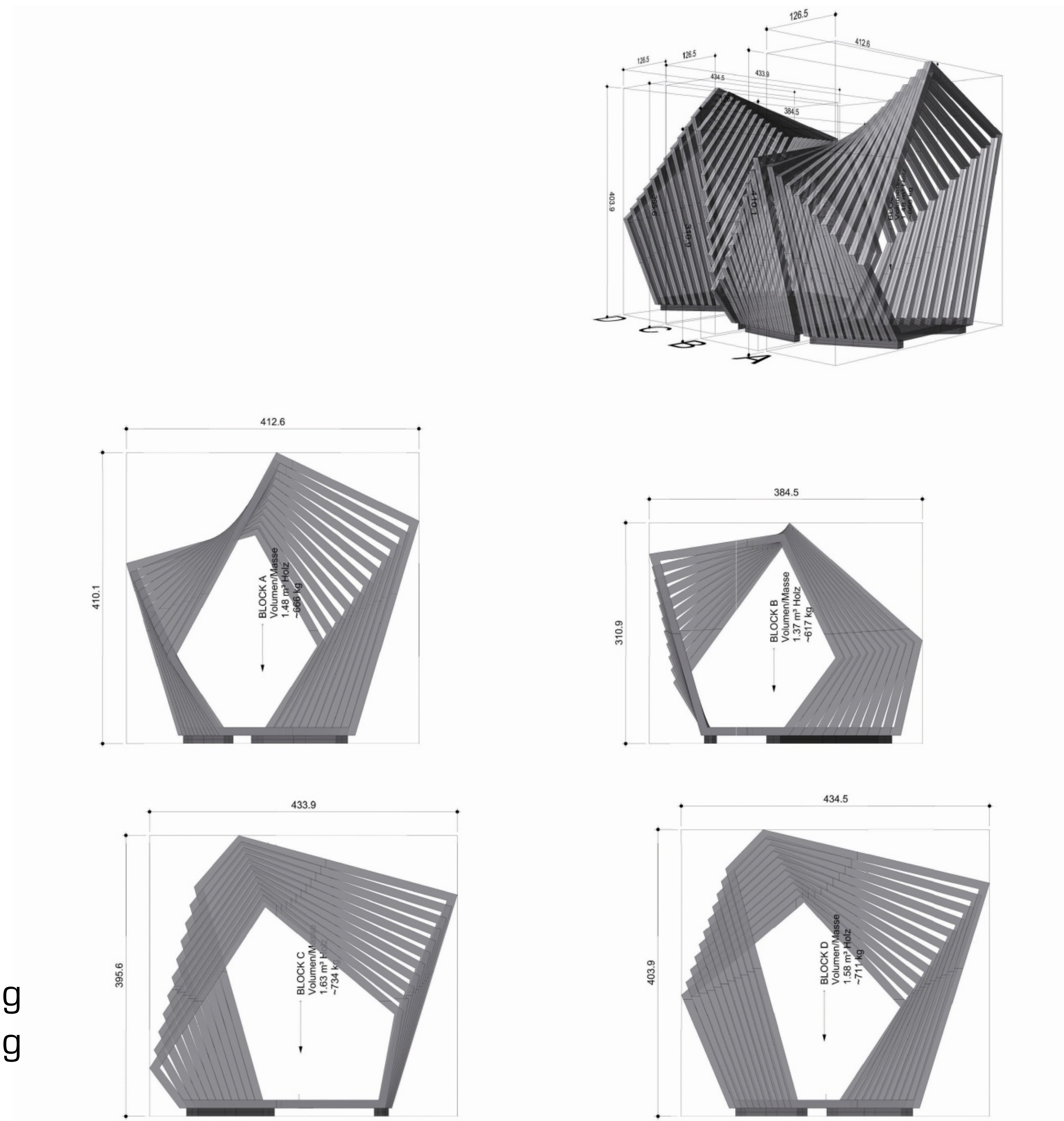


The Design Component

Evolution **from designed shape to finally defined frames** and simulating different load situations.

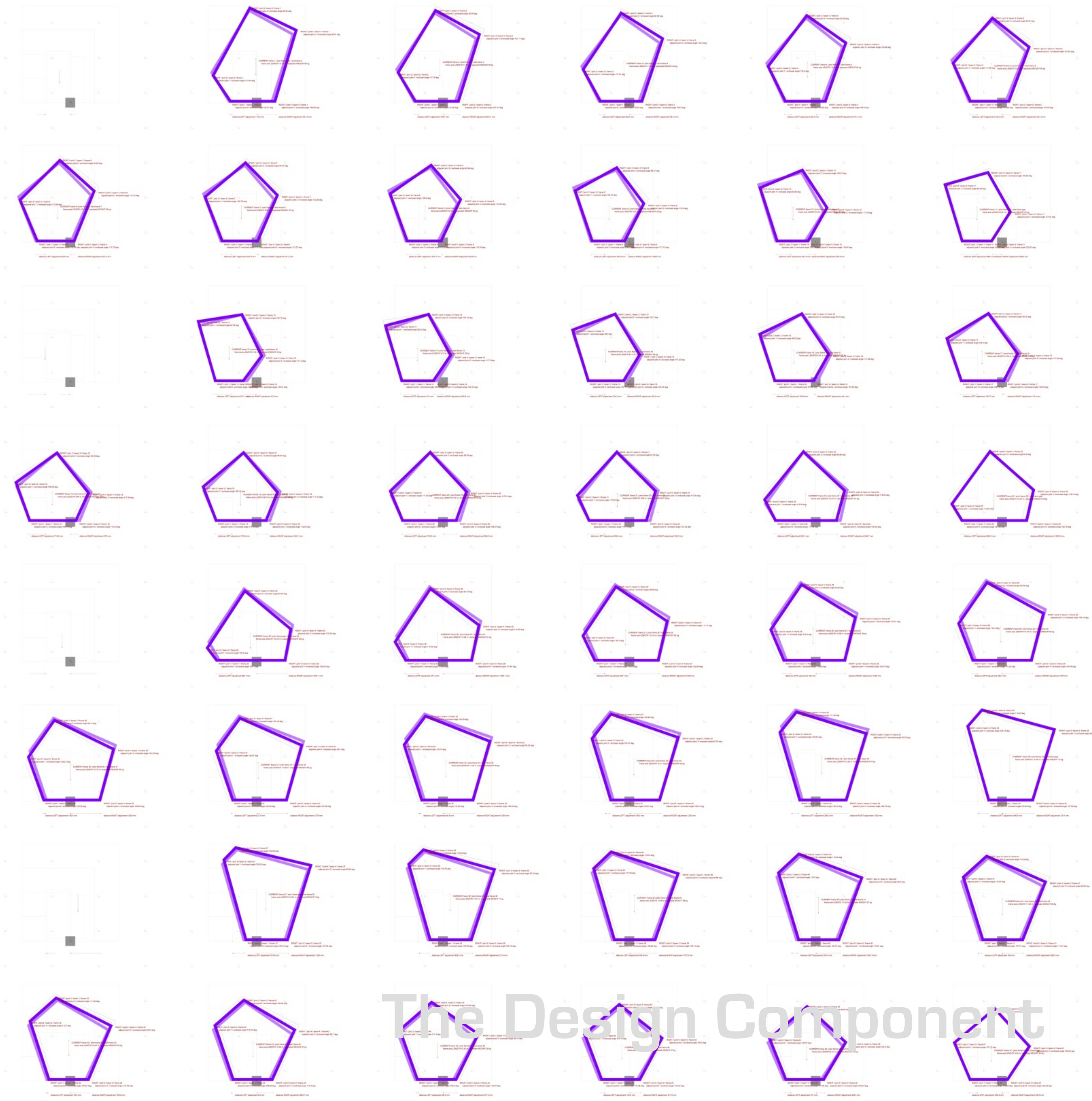


Beside aesthetics, transport dimensions, given wood measurements and other boundary conditions, structural analysis is one of the biggest influences to construct our rigid wood frame structure. In collaboration with the Institute of Structural Design it was possible to define maximum beam length according to its cross section and the crease angle range between each wooden beam **without any external fastener and fixing**.



All drawings, production lists, mounting instructions as well as material nesting results were **generated on the fly**.

The Design Component



FRAME 1 BEAM 0 full lenght 196,4 cm	FRAME 2 BEAM 3 full lenght 217,6 cm	FRAME 4 BEAM 1 full lenght 178,5 cm	FRAME 5 BEAM 4 full lenght 251,2 cm	FRAME 7 BEAM 2 full lenght 230,9 cm	FRAME 9 BEAM 0 full lenght 147,3 cm	FRAME 10 BEAM 3 full lenght 198,3 cm
FRAME 1 BEAM 1 full lenght 142,1 cm	FRAME 2 BEAM 4 full lenght 300,1 cm	FRAME 4 BEAM 2 full lenght 276,9 cm	FRAME 6 BEAM 0 full lenght 168,6 cm	FRAME 7 BEAM 3 full lenght 200,5 cm	FRAME 9 BEAM 1 full lenght 230,3 cm	FRAME 10 BEAM 4 full lenght 173,2 cm
FRAME 1 BEAM 2 full lenght 331,3 cm	FRAME 3 BEAM 0 full lenght 184,8 cm	FRAME 4 BEAM 3 full lenght 208,4 cm	FRAME 6 BEAM 1 full lenght 197,3 cm	FRAME 7 BEAM 4 full lenght 219,3 cm	FRAME 9 BEAM 2 full lenght 208,3 cm	FRAME 11 BEAM 0 full lenght 133,9 cm
FRAME 1 BEAM 3 full lenght 225,2 cm	FRAME 3 BEAM 1 full lenght 164,8 cm	FRAME 4 BEAM 4 full lenght 267,4 cm	FRAME 6 BEAM 2 full lenght 244,9 cm	FRAME 8 BEAM 0 full lenght 153,3 cm	FRAME 9 BEAM 3 full lenght 199,5 cm	FRAME 11 BEAM 1 full lenght 264,6 cm
FRAME 1 BEAM 4 full lenght 318,7 cm	FRAME 3 BEAM 2 full lenght 294,4 cm	FRAME 5 BEAM 0 full lenght 171,9 cm	FRAME 6 BEAM 3 full lenght 202,2 cm	FRAME 8 BEAM 1 full lenght 219,3 cm	FRAME 9 BEAM 4 full lenght 188,3 cm	FRAME 11 BEAM 2 full lenght 196,2 cm
FRAME 2 BEAM 0 full lenght 189,8 cm	FRAME 3 BEAM 3 full lenght 212,6 cm	FRAME 5 BEAM 1 full lenght 186,3 cm	FRAME 6 BEAM 4 full lenght 235,1 cm	FRAME 8 BEAM 2 full lenght 218,6 cm	FRAME 10 BEAM 0 full lenght 141,5 cm	FRAME 11 BEAM 3 full lenght 200 cm
FRAME 2 BEAM 1 full lenght 162,3 cm	FRAME 3 BEAM 4 full lenght 283,7 cm	FRAME 5 BEAM 2 full lenght 260,3 cm	FRAME 7 BEAM 0 full lenght 169,3 cm	FRAME 8 BEAM 3 full lenght 189,5 cm	FRAME 10 BEAM 1 full lenght 243,4 cm	FRAME 11 BEAM 4 full lenght 184,6 cm
FRAME 2 BEAM 2 full lenght 312,5 cm	FRAME 4 BEAM 0 full lenght 178,3 cm	FRAME 5 BEAM 3 full lenght 264,9 cm	FRAME 7 BEAM 1 full lenght 208,2 cm	FRAME 8 BEAM 4 full lenght 203,6 cm	FRAME 10 BEAM 2 full lenght 200,4 cm	FRAME 13 BEAM 0 full lenght 128,6 cm
FRAME 13 BEAM 1 full lenght 266,9 cm	FRAME 14 BEAM 4 full lenght 141,1 cm	FRAME 16 BEAM 2 full lenght 205,7 cm	FRAME 18 BEAM 0 full lenght 204,2 cm	FRAME 19 BEAM 3 full lenght 228,5 cm	FRAME 21 BEAM 1 full lenght 127,8 cm	FRAME 22 BEAM 4 full lenght 141,3 cm
FRAME 13 BEAM 2 full lenght 194 cm	FRAME 15 BEAM 0 full lenght 157,9 cm	FRAME 16 BEAM 3 full lenght 214,3 cm	FRAME 18 BEAM 1 full lenght 178,6 cm	FRAME 19 BEAM 4 full lenght 139,9 cm	FRAME 21 BEAM 2 full lenght 254,1 cm	FRAME 23 BEAM 0 full lenght 278,8 cm
FRAME 13 BEAM 3 full lenght 202,3 cm	FRAME 15 BEAM 1 full lenght 231,5 cm	FRAME 16 BEAM 4 full lenght 140,9 cm	FRAME 18 BEAM 2 full lenght 218,8 cm	FRAME 20 BEAM 0 full lenght 234,2 cm	FRAME 21 BEAM 3 full lenght 240,6 cm	FRAME 23 BEAM 1 full lenght 92,8 cm
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FRAME 14 BEAM 2 full lenght 194,7 cm	FRAME 16 BEAM 0 full lenght 174,6 cm	FRAME 17 BEAM 3 full lenght 218,6 cm	FRAME 19 BEAM 1 full lenght 161,6 cm	FRAME 20 BEAM 4 full lenght 140,1 cm	FRAME 22 BEAM 2 full lenght 267,3 cm	FRAME 25 BEAM 0 full lenght 295 cm
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FRAME 25 BEAM 2 full lenght 294,8 cm	FRAME 27 BEAM 0 full lenght 274,3 cm	FRAME 28 BEAM 3 full lenght 271,9 cm	FRAME 30 BEAM 1 full lenght 201,4 cm	FRAME 31 BEAM 4 full lenght 246,9 cm	FRAME 33 BEAM 2 full lenght 141 cm	FRAME 35 BEAM 0 full lenght 193,2 cm
FRAME 25 BEAM 3 full lenght 261,1 cm	FRAME 27 BEAM 1 full lenght 126,4 cm	FRAME 28 BEAM 4 full lenght 193,8 cm	FRAME 30 BEAM 2 full lenght 200 cm	FRAME 32 BEAM 0 full lenght 223,3 cm	FRAME 33 BEAM 3 full lenght 306,2 cm	FRAME 35 BEAM 1 full lenght 328,8 cm
FRAME 25 BEAM 4 full lenght 143,6 cm	FRAME 27 BEAM 2 full lenght 265,9 cm	FRAME 29 BEAM 0 full lenght 253,6 cm	FRAME 30 BEAM 3 full lenght 283,8 cm	FRAME 32 BEAM 1 full lenght 252,5 cm	FRAME 33 BEAM 4 full lenght 281,2 cm	FRAME 35 BEAM 2 full lenght 103 cm
FRAME 26 BEAM 0 full lenght 266,2 cm	FRAME 27 BEAM 3 full lenght 267,2 cm	FRAME 29 BEAM 1 full lenght 178,9 cm	FRAME 30 BEAM 4 full lenght 227,8 cm	FRAME 32 BEAM 2 full lenght 180 cm	FRAME 34 BEAM 0 full lenght 203,2 cm	FRAME 35 BEAM 3 full lenght 322,8 cm
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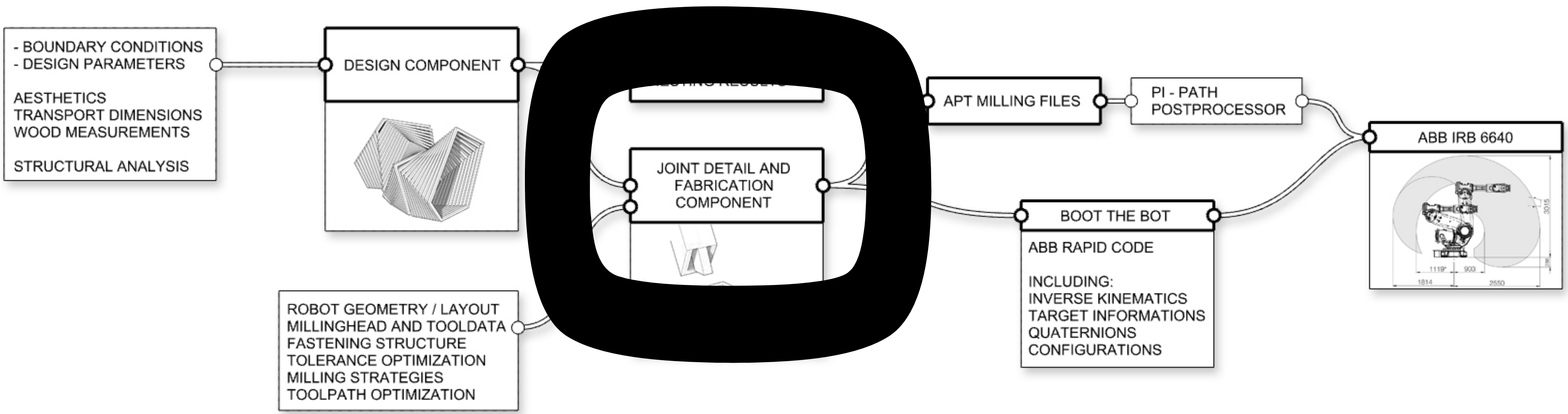
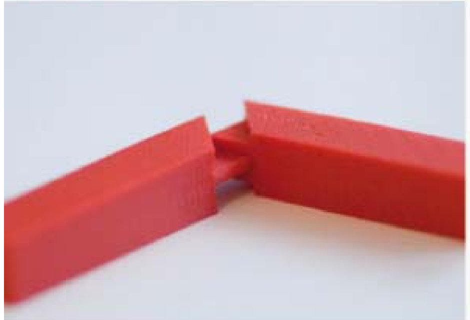
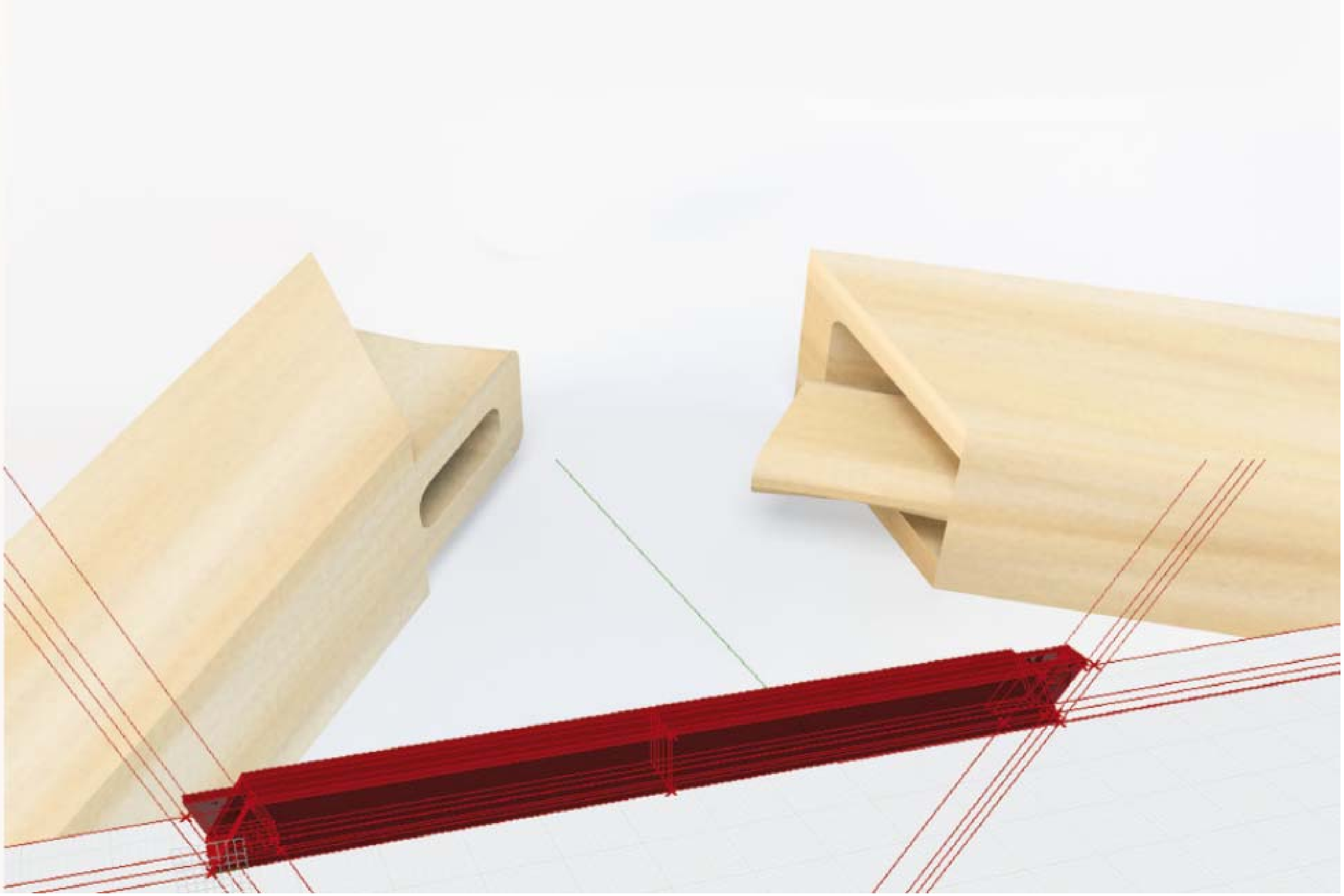
FRAME 37 BEAM 4 full lenght 333,8 cm	FRAME 39 BEAM 2 full lenght 114,8 cm	FRAME 41 BEAM 0 full lenght 177,1 cm	FRAME 42 BEAM 3 full lenght 266,3 cm	FRAME 44 BEAM 1	FRAME 45 BEAM 4	FRAME 47 BEAM
FRAME 38 BEAM 0 full lenght 181,6 cm	FRAME 39 BEAM 3 full lenght 304,3 cm	FRAME 41 BEAM 1 full lenght 283,6 cm	FRAME 42 BEAM 4 full lenght 253,3 cm	BEAM 2 full lenght 185,7 cm	FRAME 46 BEAM 0 full lenght 169 cm	FRAME 47 BEAM 3 full lenght 222,8 cm
FRAME 38 BEAM 1 full lenght 337,6 cm	FRAME 39 BEAM 4 full lenght 300,9 cm	FRAME 41 BEAM 2 full lenght 143,3 cm	FRAME 43 BEAM 0 full lenght 174,3 cm	FRAME 44 BEAM 3 full lenght 245,3 cm	FRAME 46 BEAM 1 full lenght 194,9 cm	FRAME 47 BEAM 4 full lenght 178,9 cm



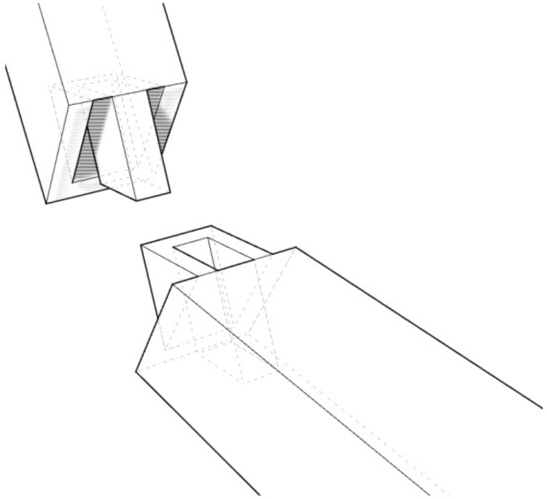
The Joint Component





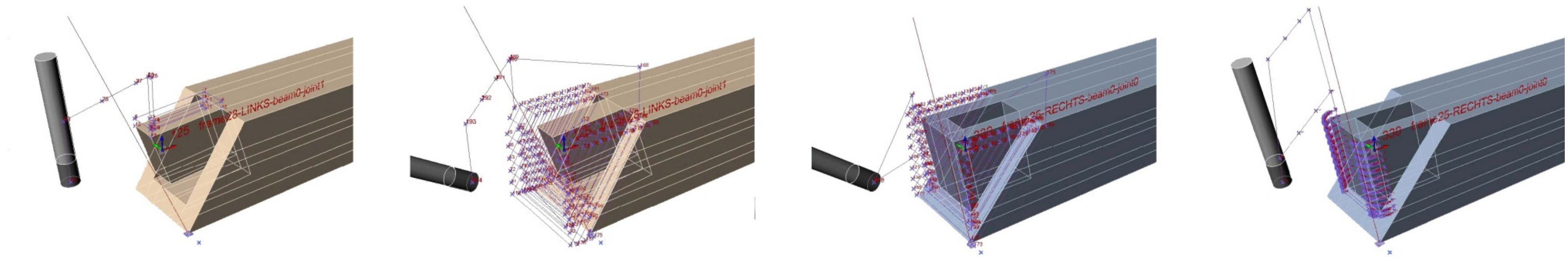


Parametric joint design



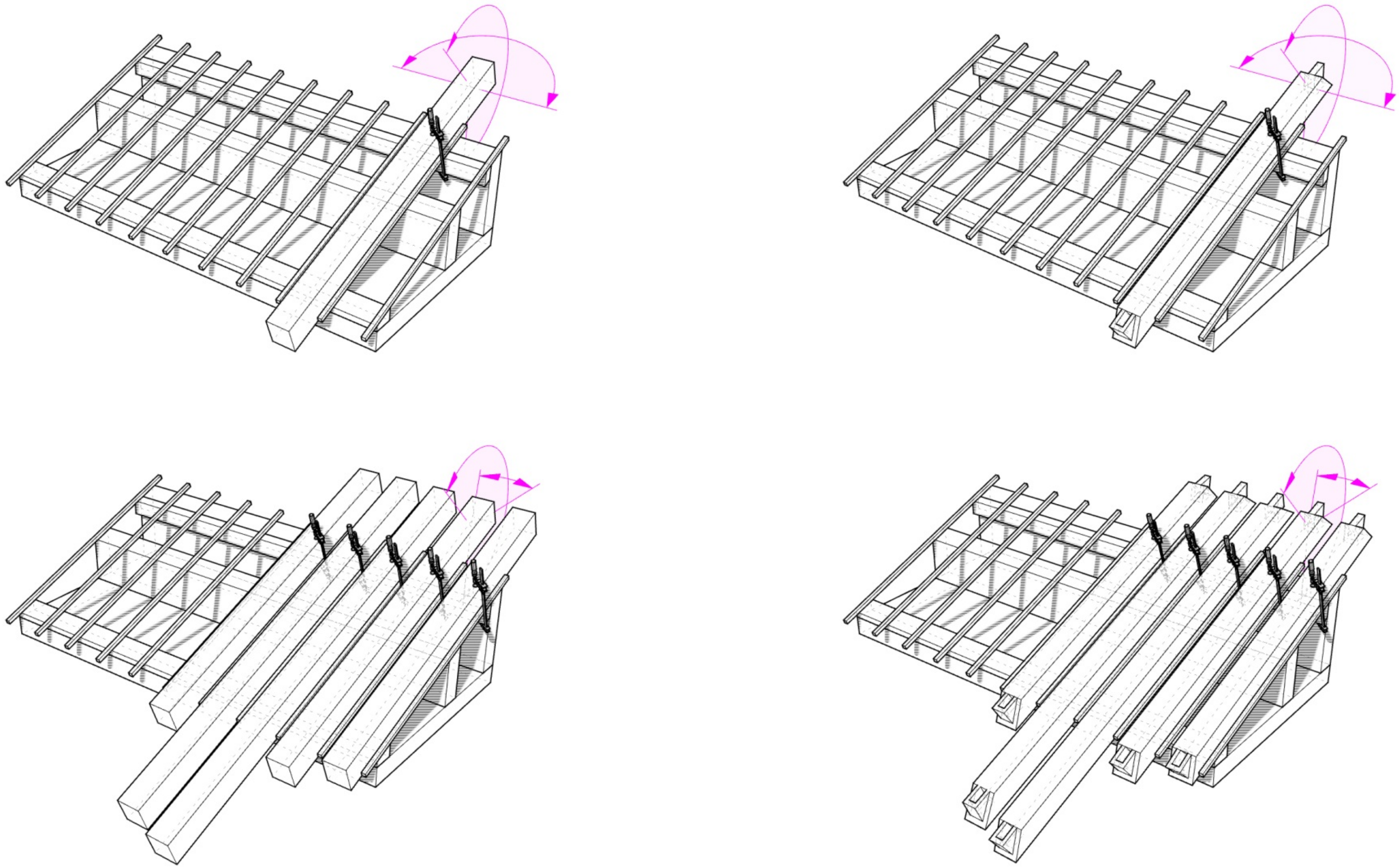
The Joint Component

Different **machining operations and milling path creation**.



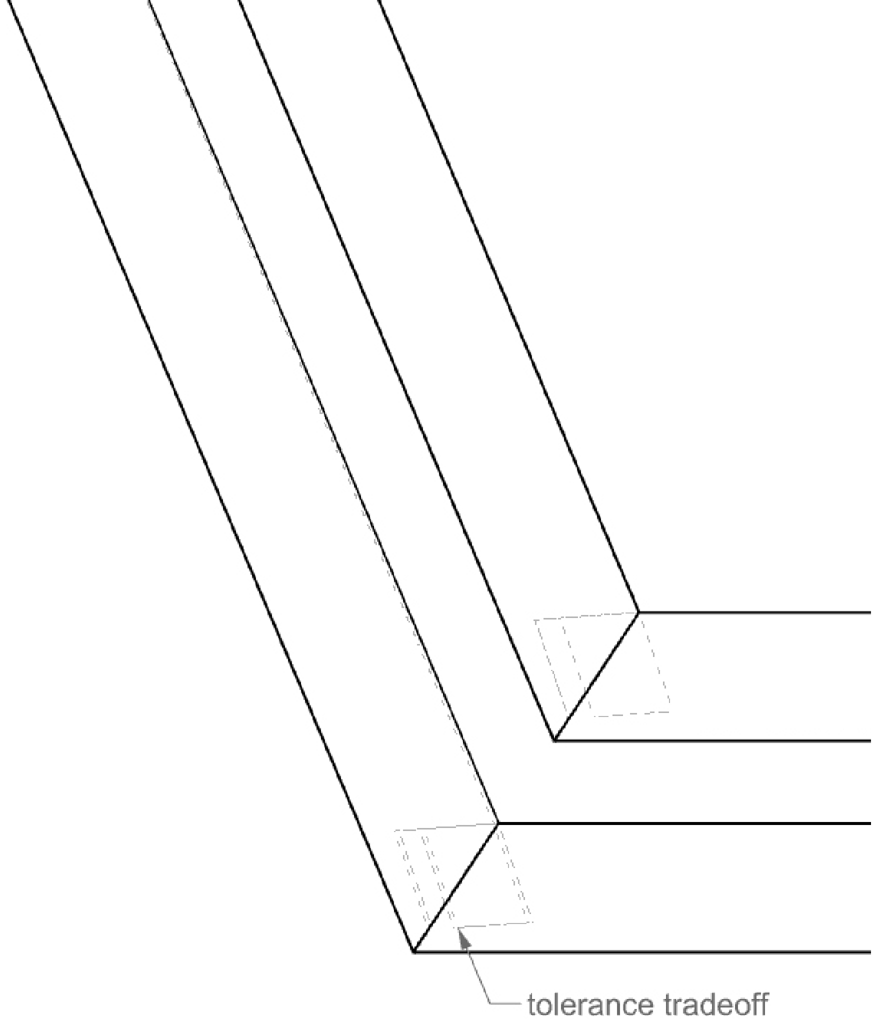
For the parametrically generation of all machining operations and tool paths following input parameters were considered:

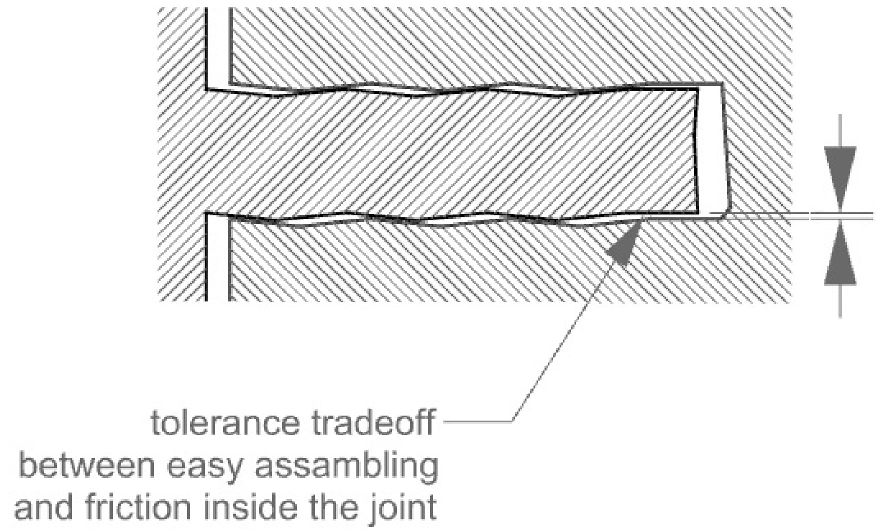
1. **Milling head for 6-axis** robot with different cylindrical tool definitions.
2. **Robot geometry** including additional linear axis for reachability simulations.
3. **Fastening structure** for beams during milling.
4. **Tolerance optimization** between easy manual assembling and best values for friction and rigidity inside the joint.
5. **Milling parameters** like cut levels, path offset distances, point step density and additional tolerances to avoid collisions.
6. **Optimization of tool paths** and strategies to reduce production time

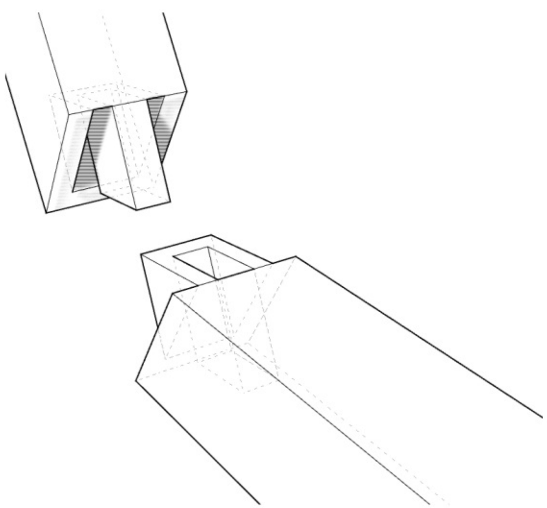


Mounting and the restrictions.

Based on all these conditions the necessary machining operations were specifically developed to generate automated production data.

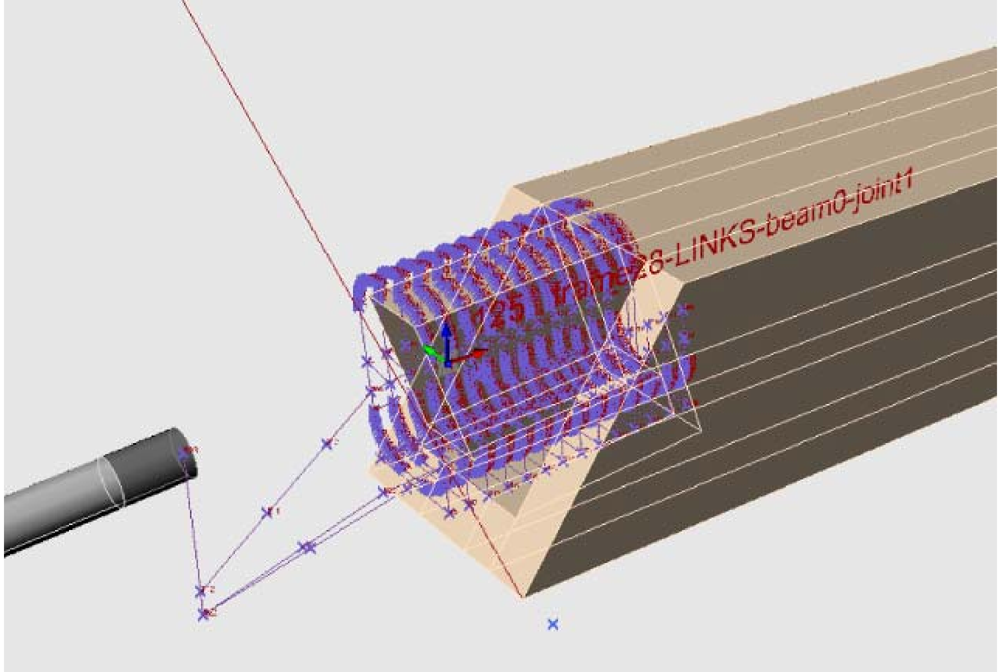


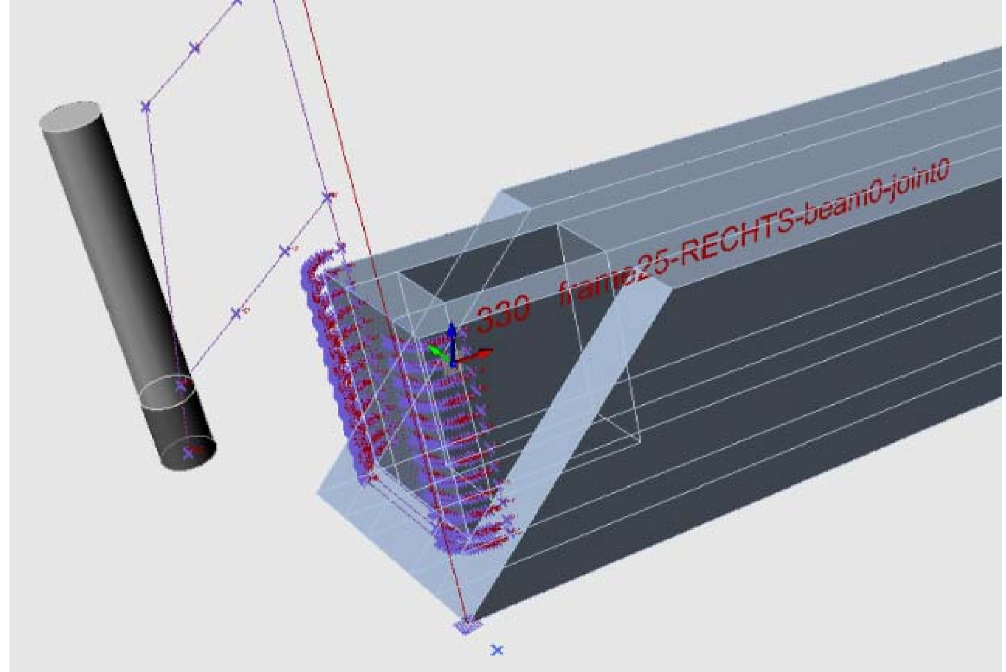




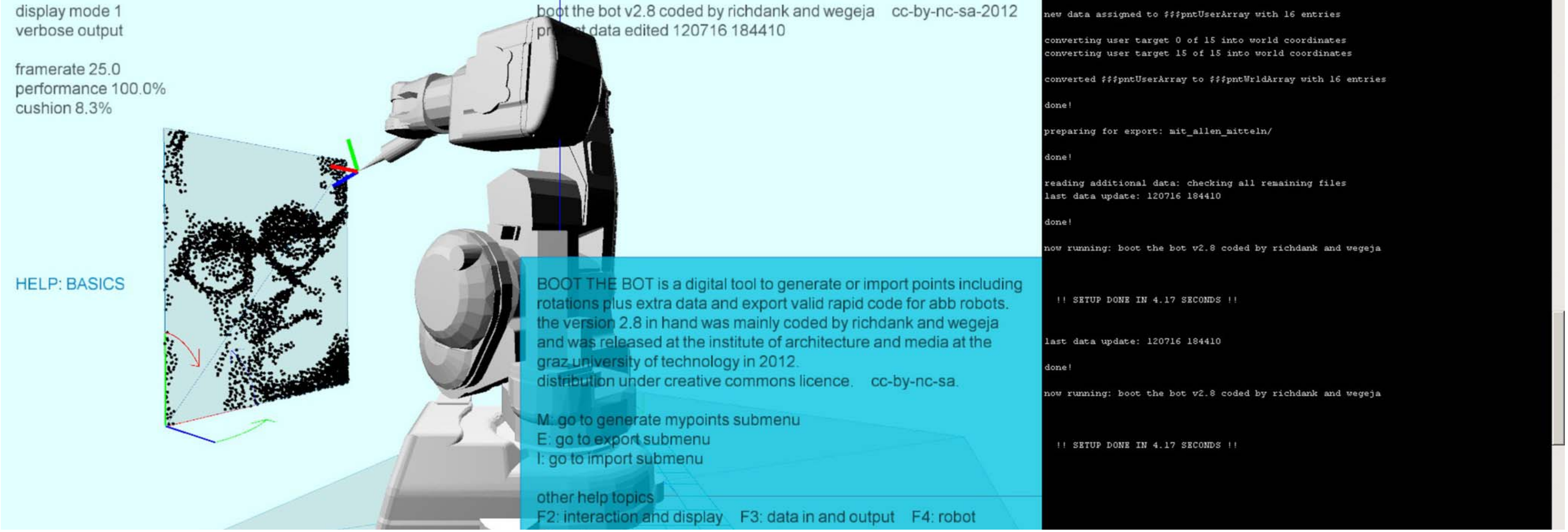
Tolerance optimization.

The Joint Component





Different **machining operations and milling path creation**.



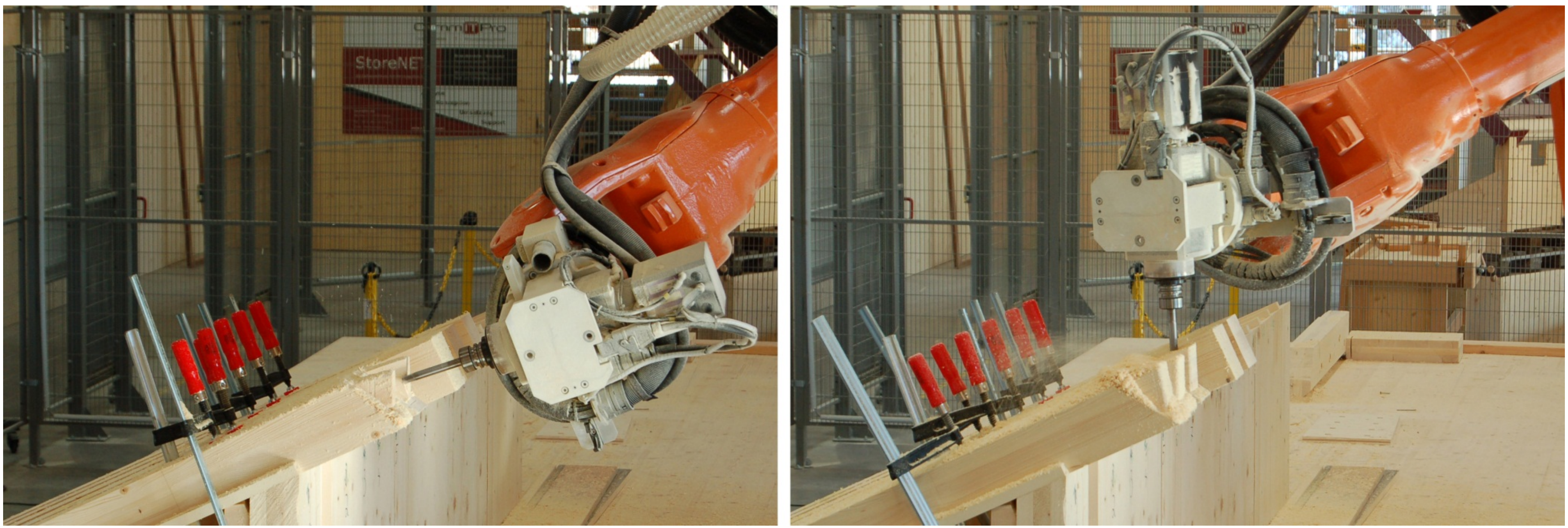
To keep different robotic production environments and robot manufacturer in mind we developed two gateways to communicate with the output devices.

1. Our component is able to **export apt milling files** which are standard in exchanging milling information as example for robot post processors like Pi-Path for ABB robots.

2. The second output format creates the possibility to **directly write and simulate entire ABB RAPID code** in real-time without intermediate steps between design environment and production – the Java or Grasshopper-based simulation, code generator and live controller for ABB robots **Boot The Bot**.

The Production of TFP

The positioned wooden beams and **robot milling head during the production** of the two parts.



The Production of TFP

The Production of TFP

The Production of TFP

Assembling pentagonal frames.

Combined to transportable units with wooden plugs driven in at the predefined **skew drill holes** and rolled into the upright position.

The Production of TFP

The Production of TFP

The Production of TFP

The Production of TFP

Acknowledgements

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Institute of Architecture and Media
Graz University of Technology
Conduct: Richard Dank, Christian Freißling and Urs Hirschberg
Assistance: Paul Pritz and Jacob Wegerer
Basic draft: Sabine Lehner
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Milling and assemblage: Thomas Bartl, Richard Dank, Christian Freißling, Alvaro Gonzalez Vergara, Stefan Haas, Georg Hansemann, Stefan Jos, Susanne Kerndle, Michael Lackner, Florian Landsteiner, Sabine Lehner, Alexander Lienhart, Stefan Nuncic, Karl Pansy, Nikolaus Pfusterschmid, Paul Pritz, Tjasa Puklavec, Paul Randig, Christian Schneeberger, Sara Vidacak, Jacob Wegerer, Felix Zmölnig and Walter Zodl
http://iam.tugraz.at/studio/w11

Realization at the
Engineering Center Wood
Holzinnovationszentrum Zeltweg
Innovationmanagement: Jörg Koppelhuber
Robotersupport: Michael Lackner
Material: Sägewerk Hans Bichler

Acknowledgements

The Framed Pavilion