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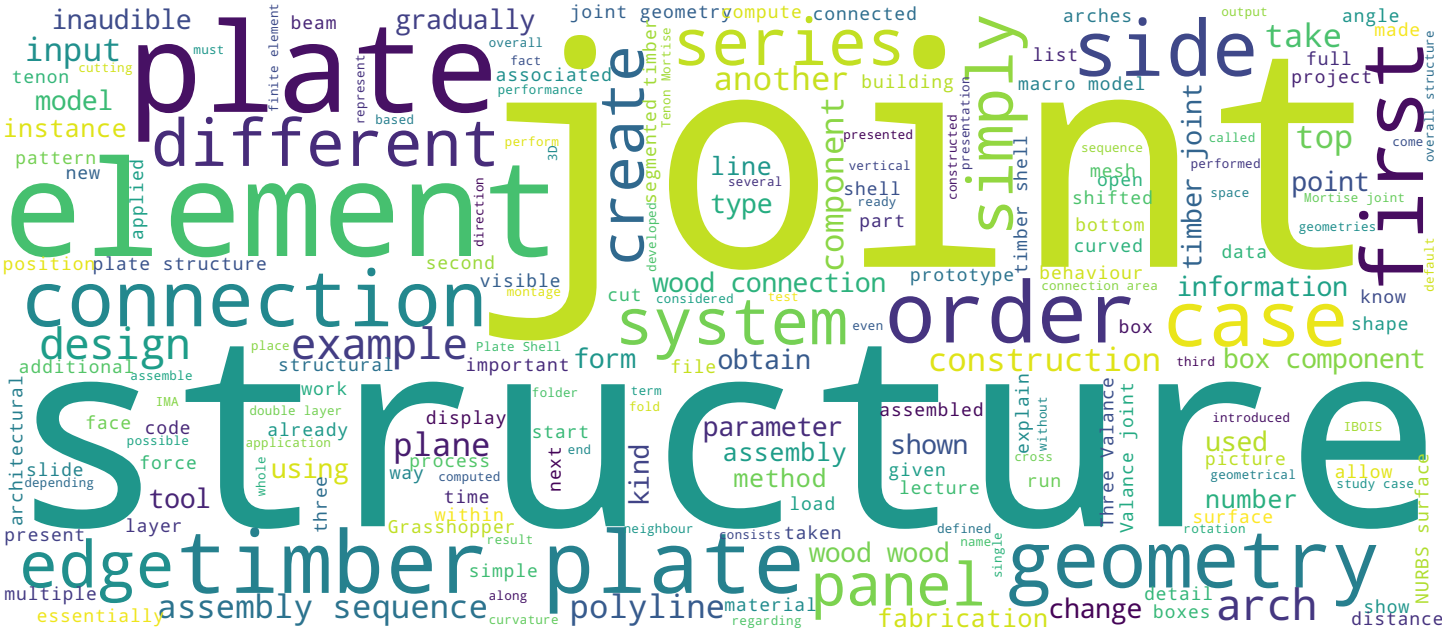
IBOIS

Advanced Timber Plate Structural Design

Double-layer Timber Plate Shell

Structure of the chapter:

- Introduction
  - Introduction to the Double-layer Timber Plate Shell
  - Software Installation
- Geometry Generation – Rhino3D, Grasshopper
  - NURBS Discretization
  - Plates
  - Joints
- Geometry Generation – Python – compas_wood
  - Code Review
  - Summary of the Method



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Video

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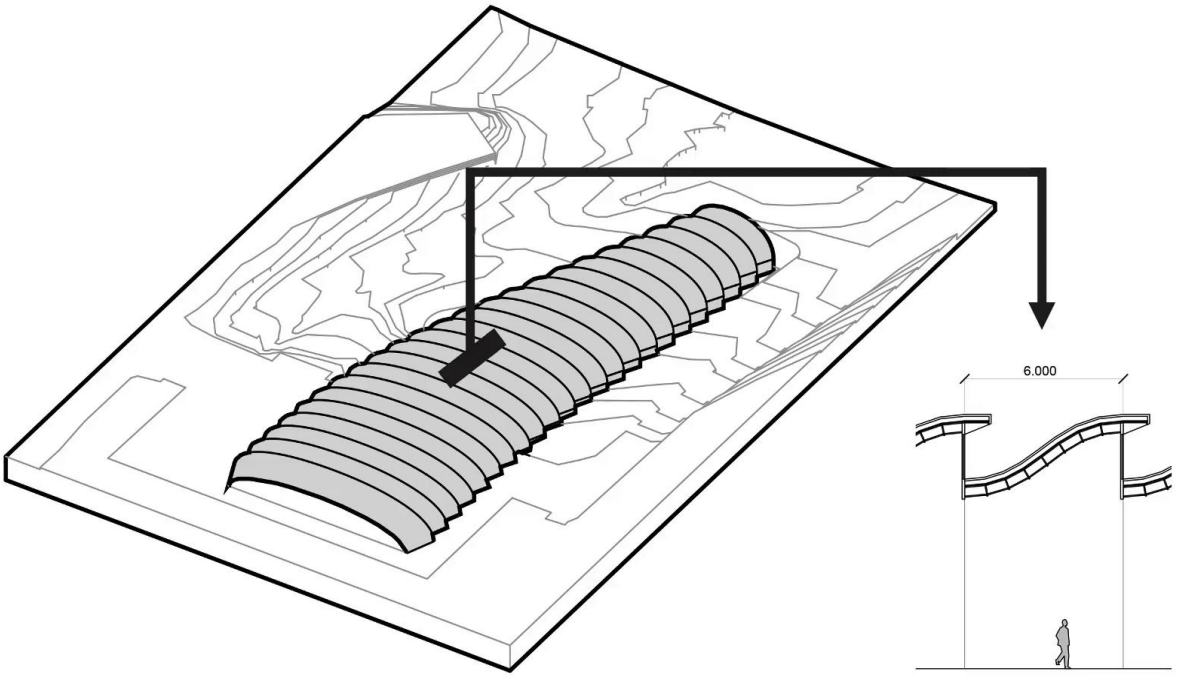
Study Case: Double-layer Timber Plate Shell

Petras Vestartas



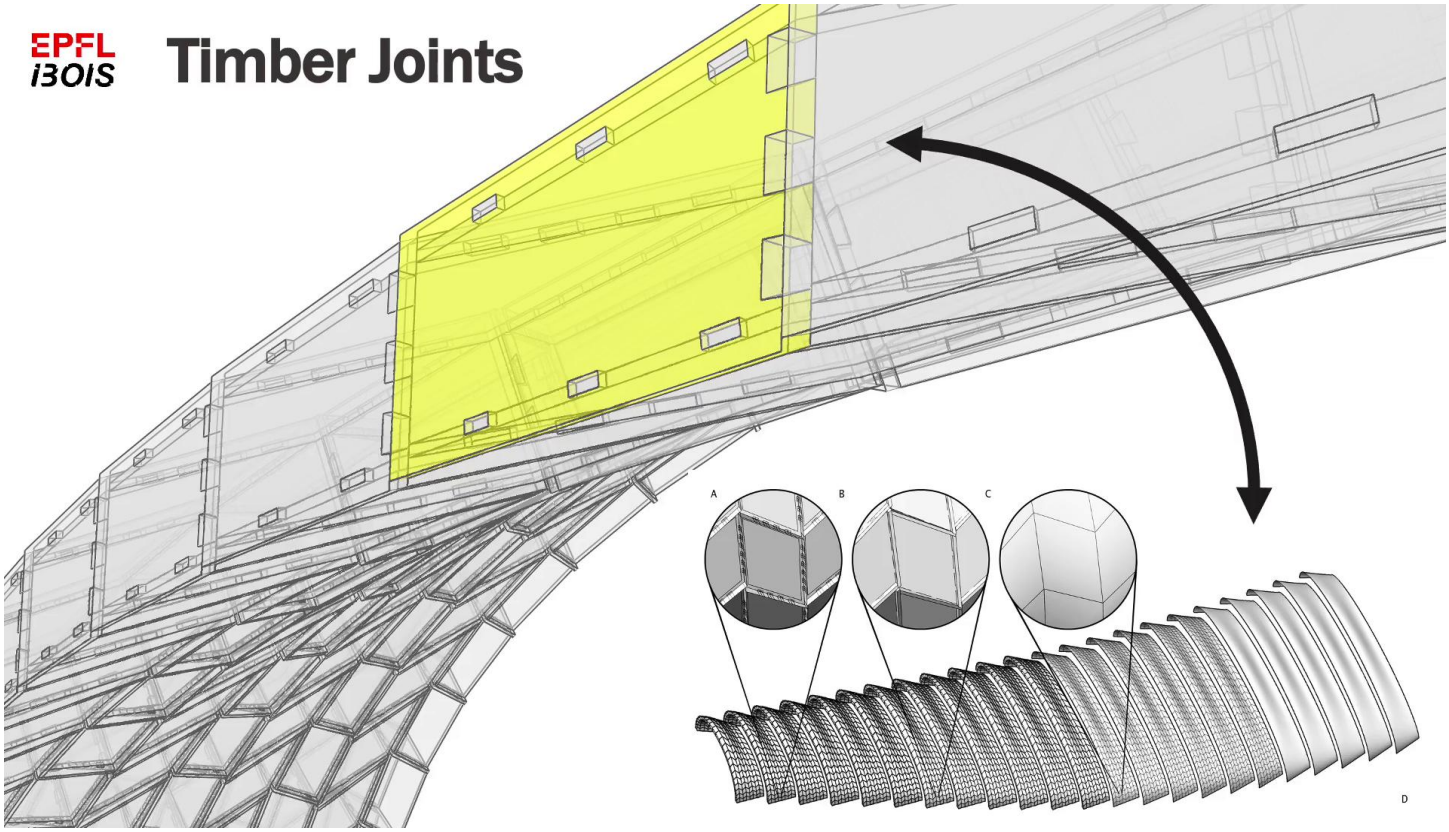
Hello, my name is Petras Vestartas. I would like to present a Double-layer Timber Plate Shell, a presentation that is composed from three parts: introduction, geometry generation for Rhino3D and Grasshopper, and finally, the concluding part using a Python-based example as a package using compass wood. I'll start from introduction. In this lecture, a study case of 23 self-similar, segmented timber arches are presented. In this picture, you can see only the global geometry but what you don't see is an actual details which is the core of this lecture.

Notes

Summary

0m 04s

Timber Joints



The goal is to explain how these NURBS surfaces are translated into visual timber plate shells. Timber plates are connected using timber joints only. In this image, you can see there is a sequence of modelling steps in order to go from the global geometry to the local geometry.

Notes

Summary

0m 43s

Modelling Steps

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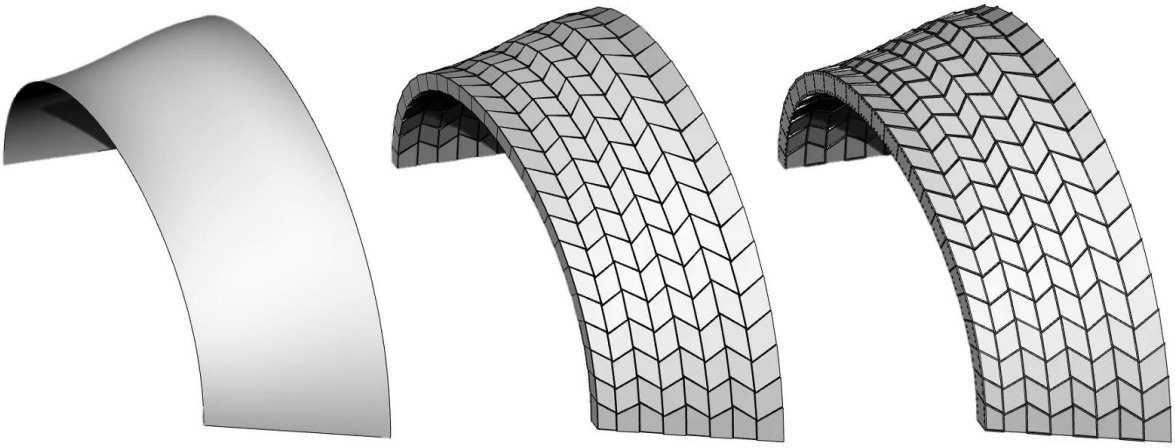

NURBS PLATES JOINTS

Practical assignment of the course will explain the modelling steps from discretization of the NURBS surface that is visible on the right side then gradually how you can create a plate geometry, in the specific case, then how you can introduce woodwork connections, also called integral mechanical attachments in more scientific literature.

Notes

Summary

1m 03s

NURBS Discreatization = Assembly Sequence

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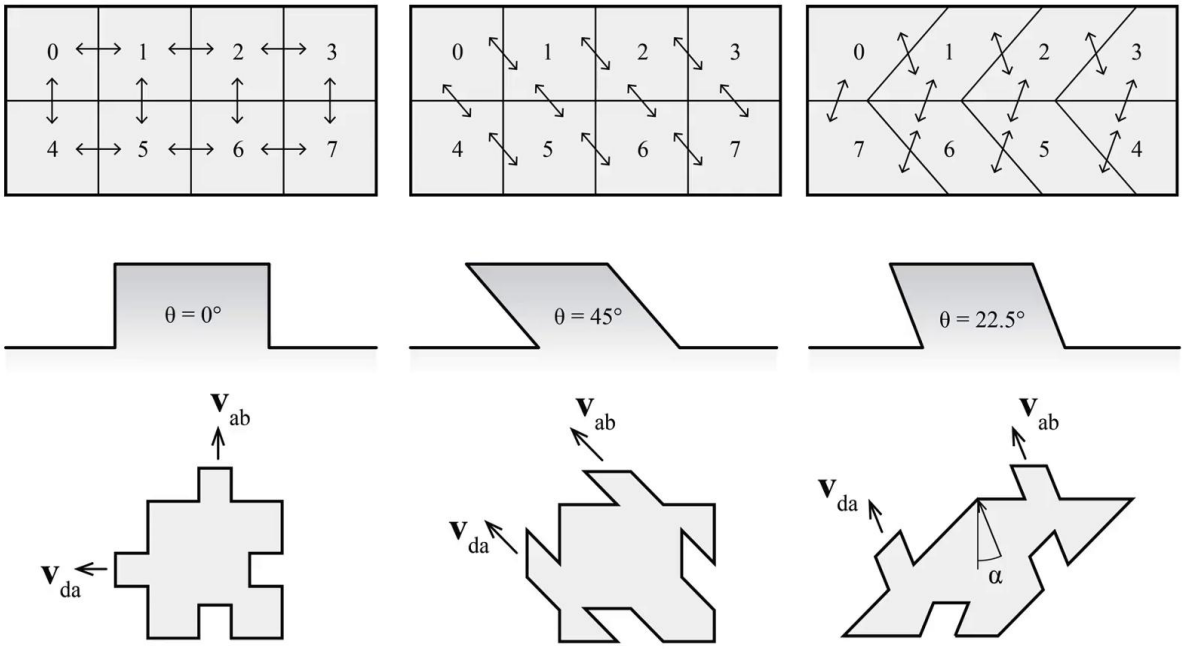


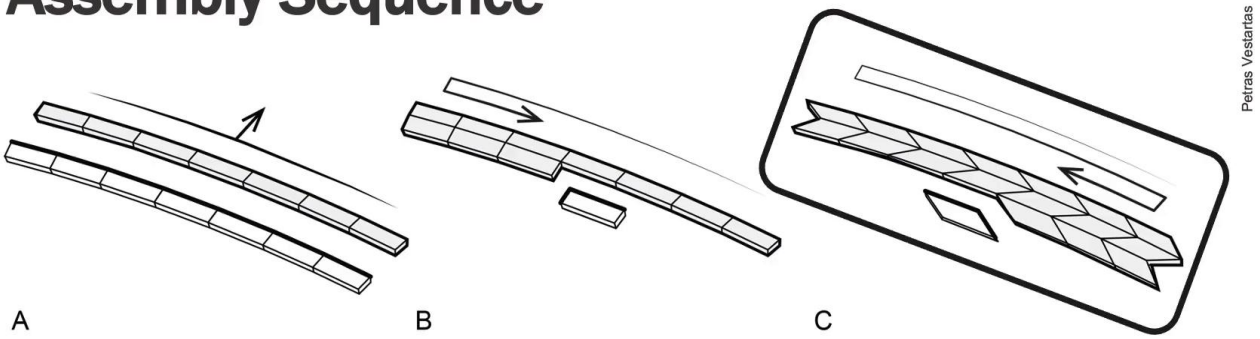
What is the key point of these structures or how to make these structures more easy to assemble? You need to pay extreme attention to the assembly sequence because if you just take a simple wood pattern, it will not allow to insert elements sequentially first, and this pattern would create a long escape path, meaning that elements can be disassembled quite easily. If you try to create a 45-degree angled Tenon-Mortise joint, will have problems of fabrication because the tool has to go really, really sharp, in relation to that table. Whereas the skewed quad pattern, also called chevron pattern, helps to block the assembly sequence while maintaining a relatively short, small angle to the plate edge.

Notes

Summary

1m 27s

Assembly Sequence



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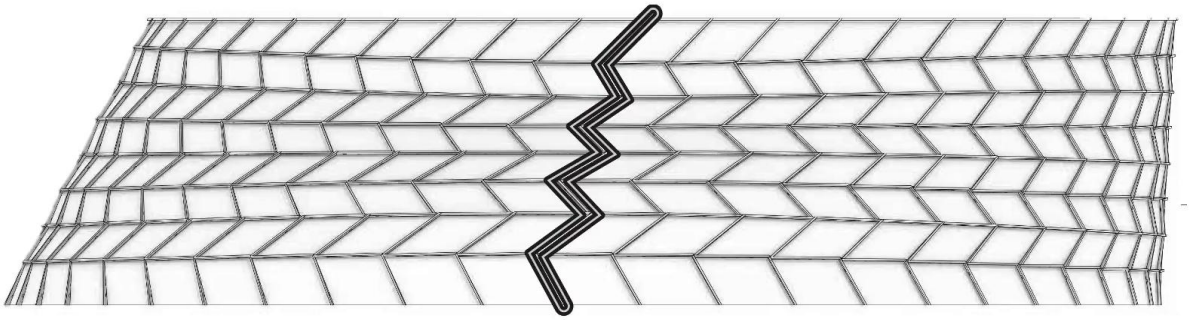

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Then comes these kind of assembly sequence in 3D. This is the picture how individual boxes, individual blocks are assembled sequentially. The third one is actually taken as a further study because of the previous mentioned explanations.

Notes

Summary

2m 19s

Assembly Sequence

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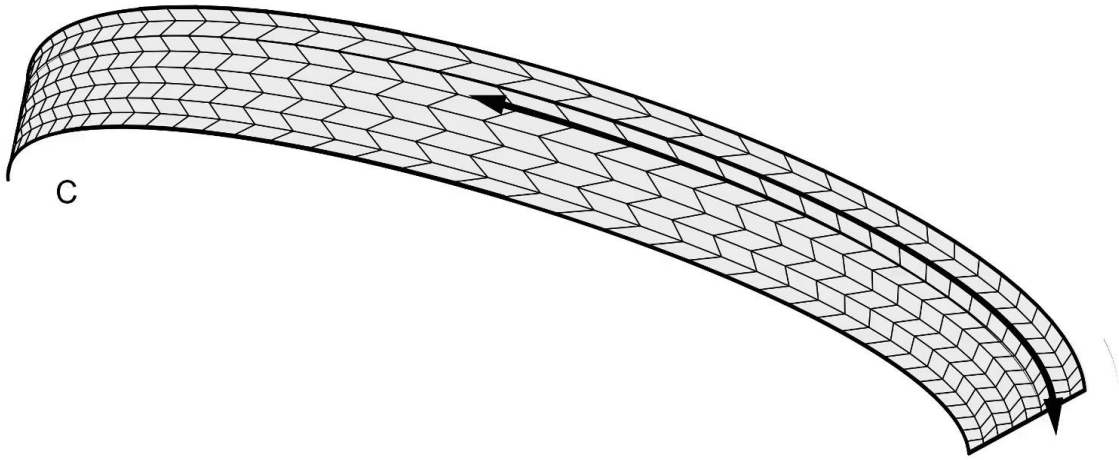


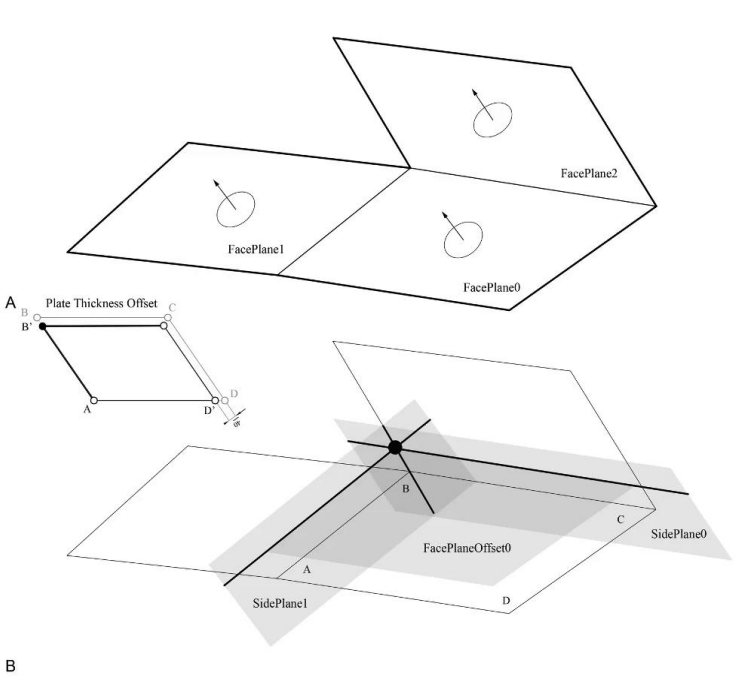
And then we kind of iterate right now in a smaller steps. First, we have the NURBS surface that we gradually subdivide into quads. And regarding of the change in curvature, the quads are subdivided into smaller elements on the bottom and they are longer on the top. And then, gradually, those elements are squeezed or skewed in order to obtain the chevron pattern or skewed pattern to ease the assembly sequence.

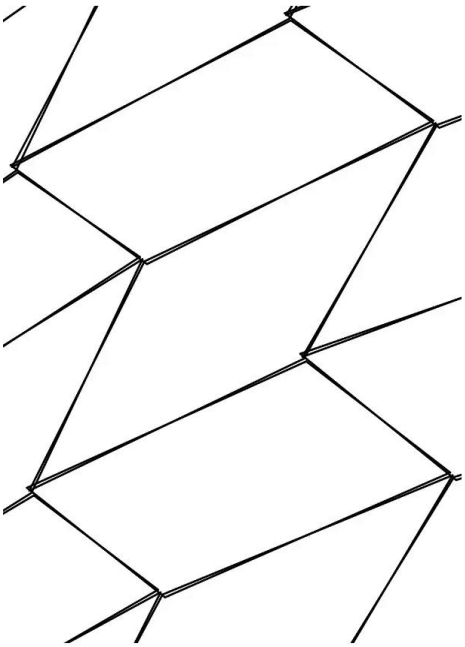
Notes

Summary

2m 38s

Planarity and Curvature





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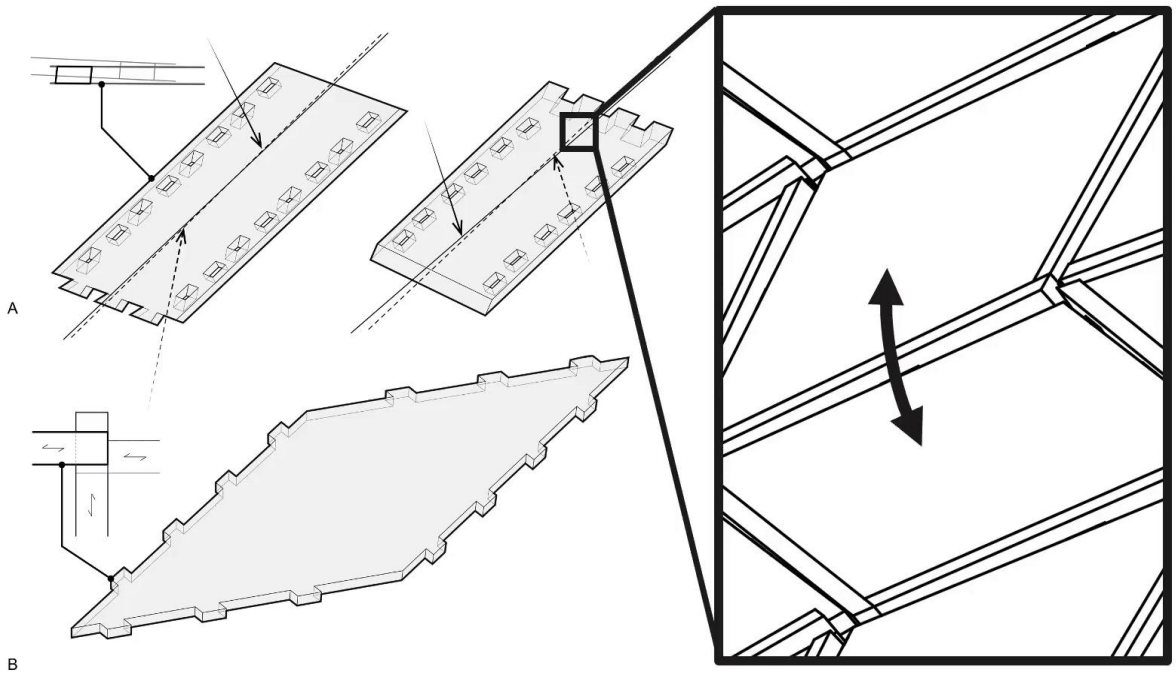
Now, the next step that we have to consider is planarisation, meaning, elements are not planar. After subdivisions, those skewed quads actually shifted because there are four points. In order to obtain the planar elements, we need to project four points of the polyline to an average plane, and we do also the same for the side edges, or simply, the edges of the mesh becomes the side plates. And then gradually, we have this plane geometry in kind of 2D sense.

Notes

Summary

3m 11s

Planarity and Curvature



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But then, it is also important to mention that this procedure is visible in actual joint geometry or timber joint geometry because, gradually, those elements rotate or shift in between the neighbours. Also, we need to take care of this condition because there is a Three-Valance joint in the end.

Notes

Summary

3m 46s

Plate Modelling - Plane and Line Intersections

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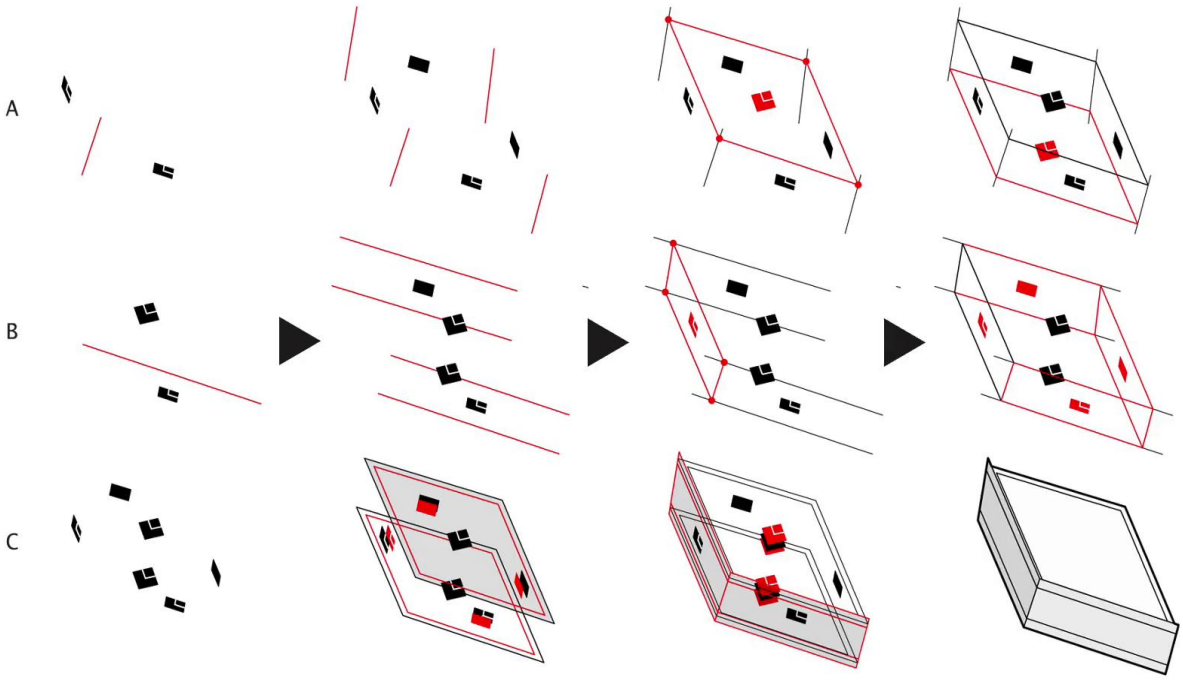

The modelling of timber joints is based on very simple but fast essential intersection methods. First one is a plane-to-plane intersection in order to obtain an infinite line. Also, a line-to-plane intersection to obtain a point. From these two essential methods, we can obtain a planar polyline, and then we can obtain a series of polylines that gradually represent the top and bottom outline.

Notes

Summary

4m 08s

Joint Types

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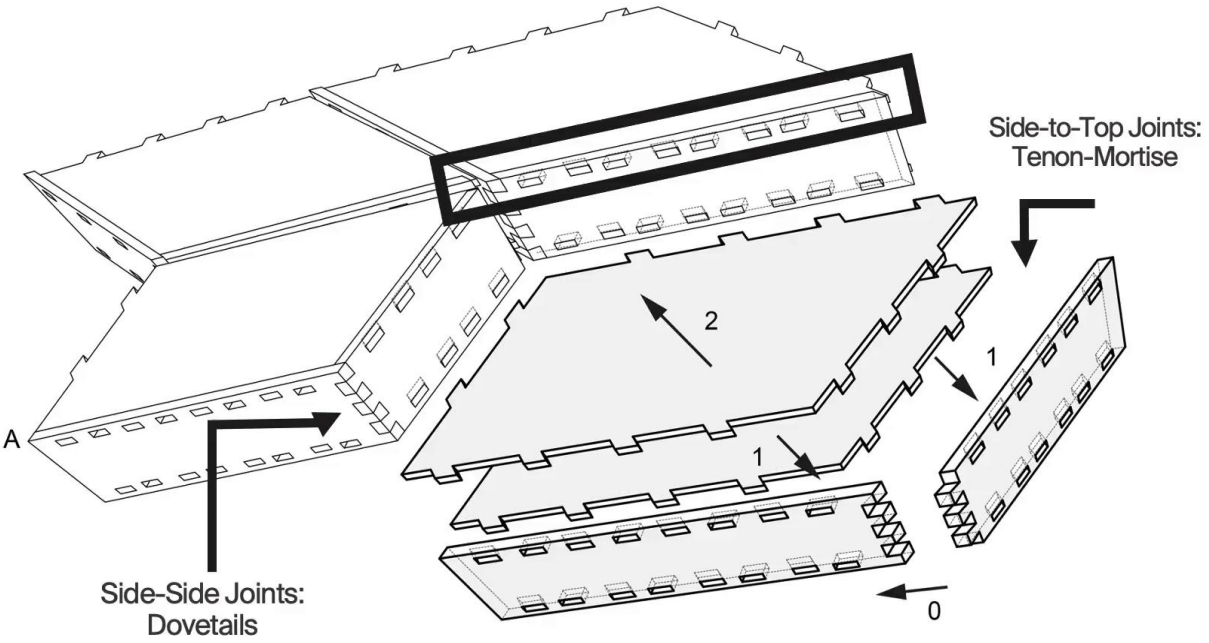

Lastly, you need to implement the joint geometry. Essentially, you need to introduce joints on each edge of the plate, these kind of edge joints. There are two types of joints. The first joint is a side-to-side Dovetail joint, and then there is a side-to-top connection, meaning, that there is a Tenon-Mortise joint as well. Lastly, there is a special case called a Three-Valance joint, when two plates are connected by one sideplate, meaning that the rotation and planarisation has to be considered in this special joint case.

Notes

Summary

4m 40s

Box Component

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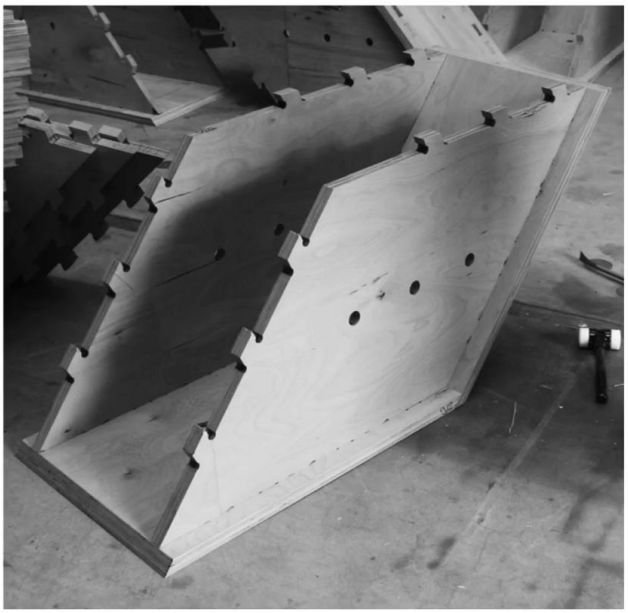

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Each mesh is transformed into box components from these planar elements to these four-centimetre thick plates of timber. This is one module, one box component that gradually constructs the overall timber shell.

Notes

Summary

5m 20s

The Three-Valence Joint

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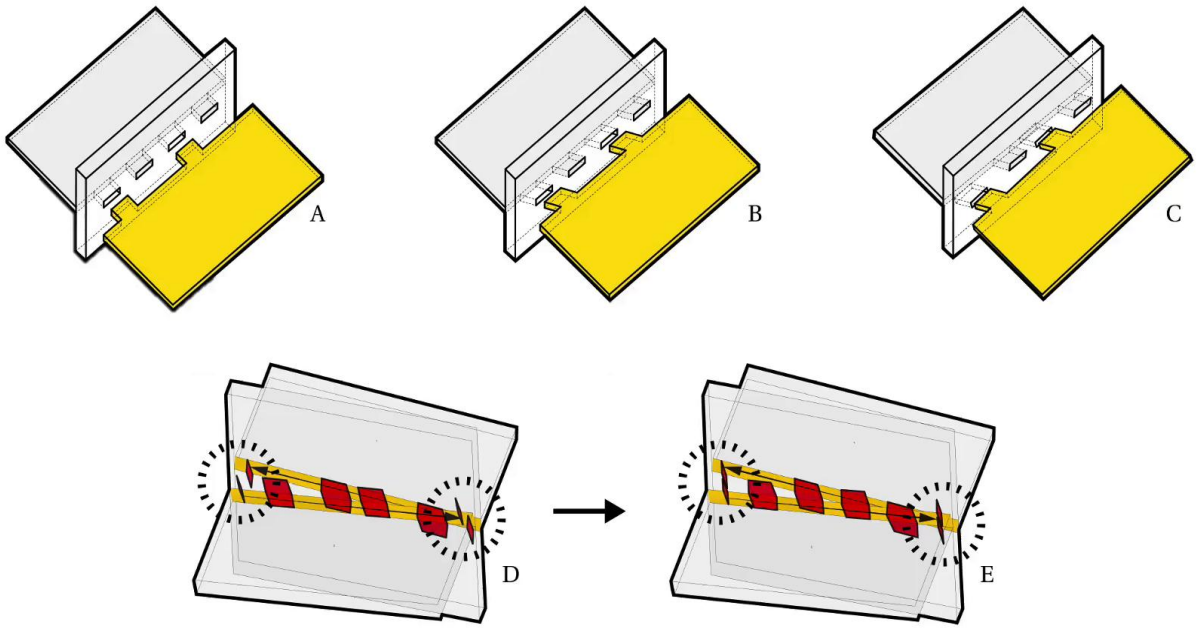

The Three-Valance joint, as mentioned before, is important because it has to be treated differently. Since distance between each term might not be properly aligned, they can be rotated, they can be shifted, there can be more joints in one connection than in another. Therefore they need to be aligned by computing the average orange connection area, as visible in the picture below. Once you compute the key equal distribution of tenons, the box component and the overall structure is ready.

Notes

Summary

5m 38s

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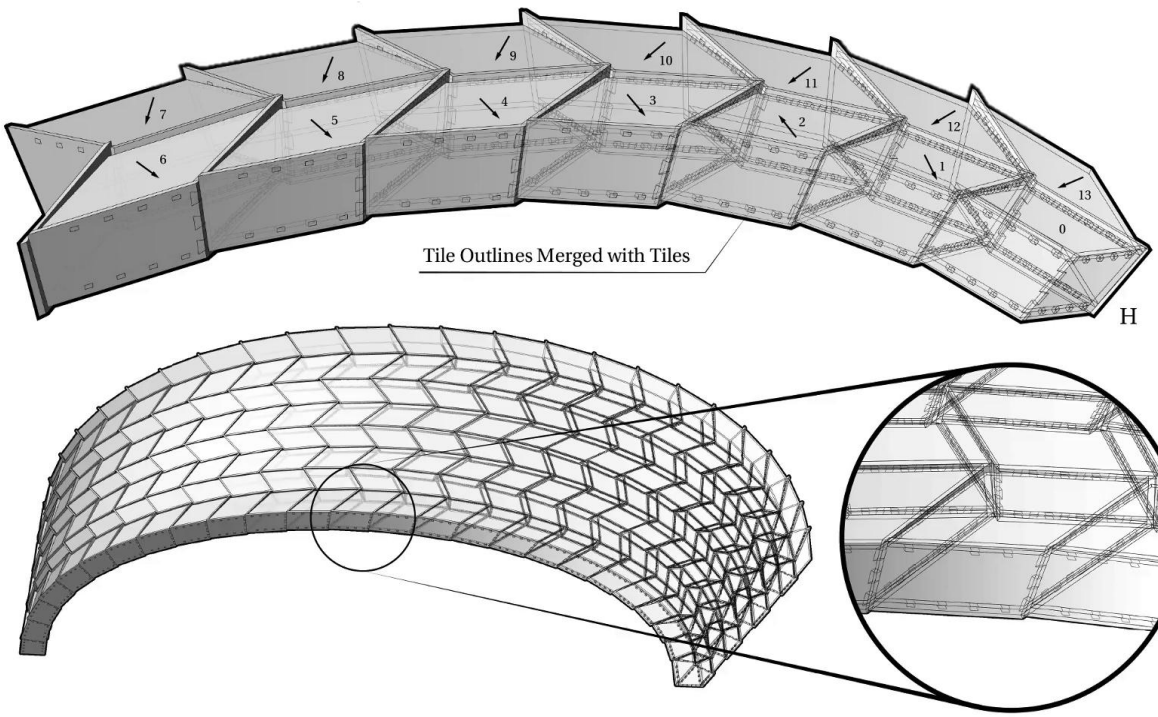

The local connection condition is repeated within the area of box components, meaning, you have those connection areas detected first, in order to know that there is actually a possibility to create a joint. Then the joint geometry is merged with the outlines of the plates. We don't perform any Boolean intersections or E-wraps, meshes curves. We simply have to know where to insert that timber joint on specific edge of the plate. We do that in order to have as fast computational time as possible. But if you do it well, if you do it correctly, you can extrapolate from a simple arch to the overall structure of the segmented timber shell, which is, essentially, the study case presented here.

Notes

Summary

6m 12s

CNC Fabrication

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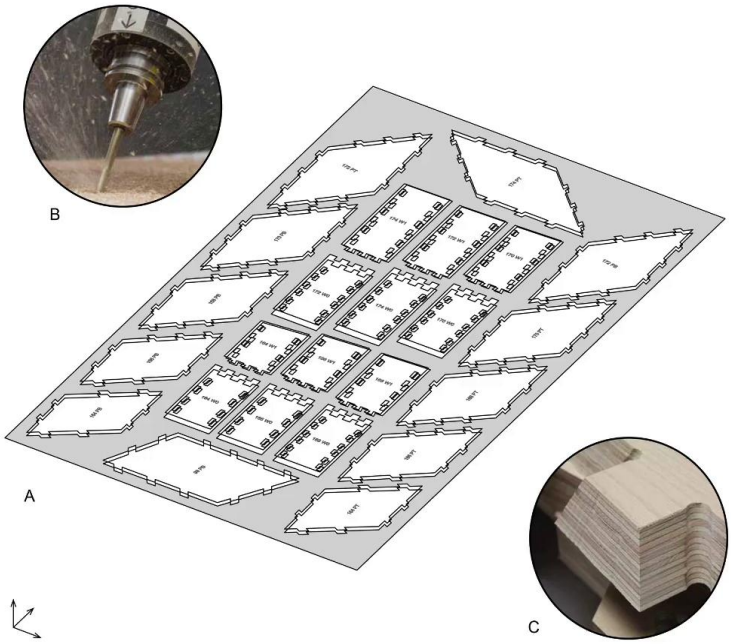


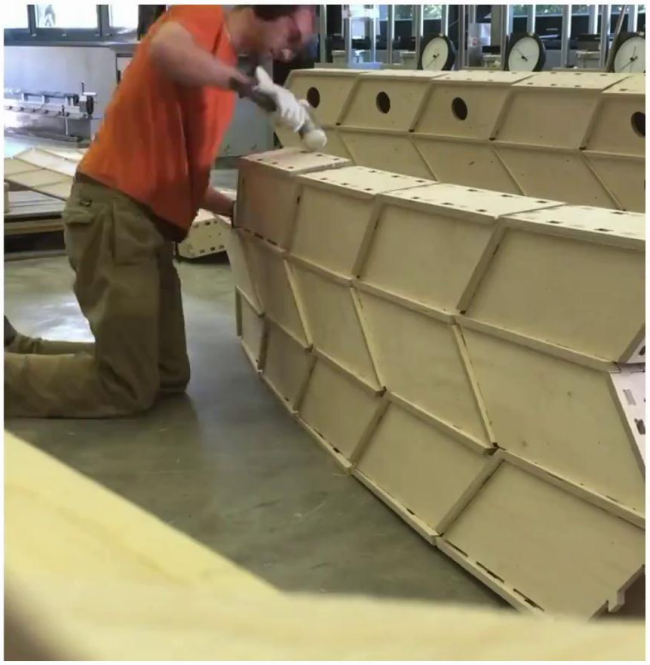
Finally, elements are fabricated using five axis-sensing machine to varying degree of angles of the joints. Each element are indexed using stickers, not engraving, but simply adding stickers manually.

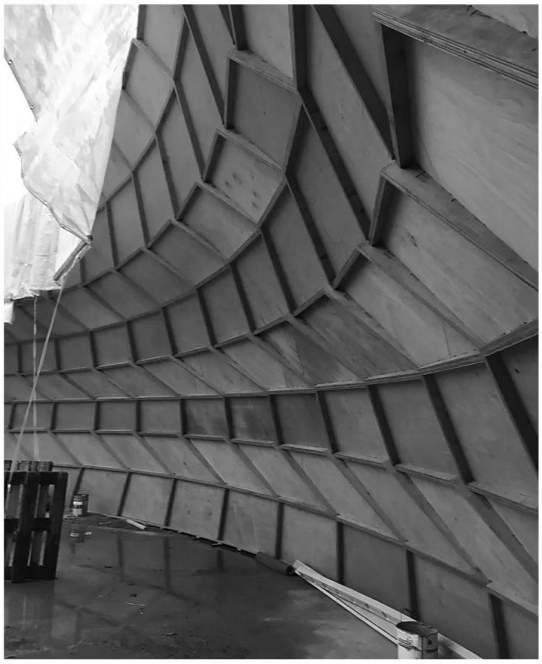
Notes

Summary

7m 00s

Assembly





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The assembly sequence of the small prototype is actually the same, or close to the same, to the full scale prototype, meaning that the arch is assembled by lying on one side, on the longitudinal side, and this has to be also taken into geometry description.

Notes

Summary

7m 16s

Assembly

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Each shell then requires a special detailing because it's not only a pavilion, it's actually the build project. There is some details and there's actually connection between individual shells. So these are the four project stages.

Notes

Summary

7m 33s

Assembly

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Since each arch is constructed on the longitudinal side, these arches actually rotated 90 degrees by a crane, and then they are lifted to foundations on actual position of the arch.

Notes

Summary

7m 49s