Lehrstuhl für Tragwerksplanung
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ASYMPTOTIC GRIDSHELL

Using asymptotic lines to construct the curved support structure of a minimal surface

Studio: Experimental Structures, 2016 Prof. Dr.-Ing. Rainer Barthel Supervision: Eike Schling Design: Denis Hitrec

Experimental Structures *is a research studio held annually at the Chair of Structural Design, Technische Universität München. We are searching for methods to* ***simplify*** *the construction of double curved surfaces. Through physical and computational experiments we demonstrate new possibilities for an intelligent symbiosis of form, structure and fabrication.*

Curvature of Lines on Surfaces

A line on a surface can have three types of curvature:
normal curvature, **geodesic curvature** and **geodesic torsion**
Imagine an ant walking along a surface. To follow the implied line, the ant must either walk up or downhill to follow the **normal curvature**; it could turn left or right to follow the **geodesic curvature**; or it must turn around the axis of the line to be able to stand with its legs straight on the surface – this is called the **geodesic torsion**. (Tang, Kilian, Vo, Wallner, Pottmann, AAG 2016)

By omitting one of the three curvature types we can create specific line networks, which have decisive advantages for the construction of **curved support structures**. Figure 1 shows the different types of curvature (*left*) and their related curve networks. We can construct support structures along these networks by simply bending or twisting certain profiles.

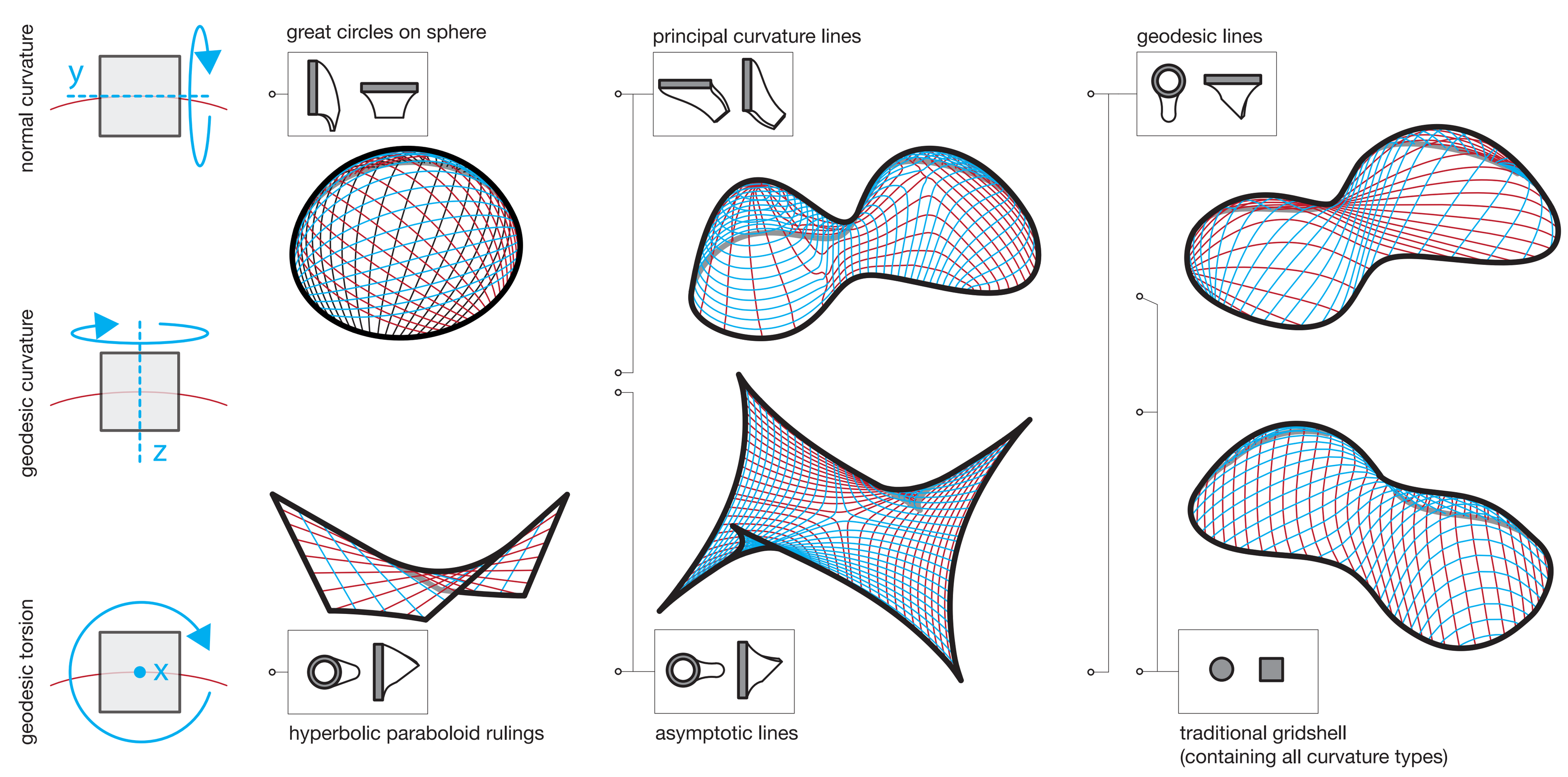

Fig.1: Shown above are specific line networks, which are based on a constant value k=0 of either their normal curvature, geodesic curvature or geodesic torsion. This has an influence on the constructibility, as indicated by the bending or twisting of the respective profiles.

Asymptotic Lines

At any point on an anticlastic surface there are two asymptotic directions. They are the direction of **zero normal curvature**. If we follow these directions, step by step, we can generate an asymptotic line. This curve will only turn sideways (geodesic curvature), but never up or down (normal curvature).

Curved beams that run along asymptotic lines and are oriented orthogonally to the surface can be unrolled to become straight strips. This is a **decisive advantage for fabrication and material efficiency** (Fig. 2). Furthermore, on a minimal surface, these „asymptotic strips“ always intersect at 90 degrees. This allows for a simplified construction with rectangular joints.

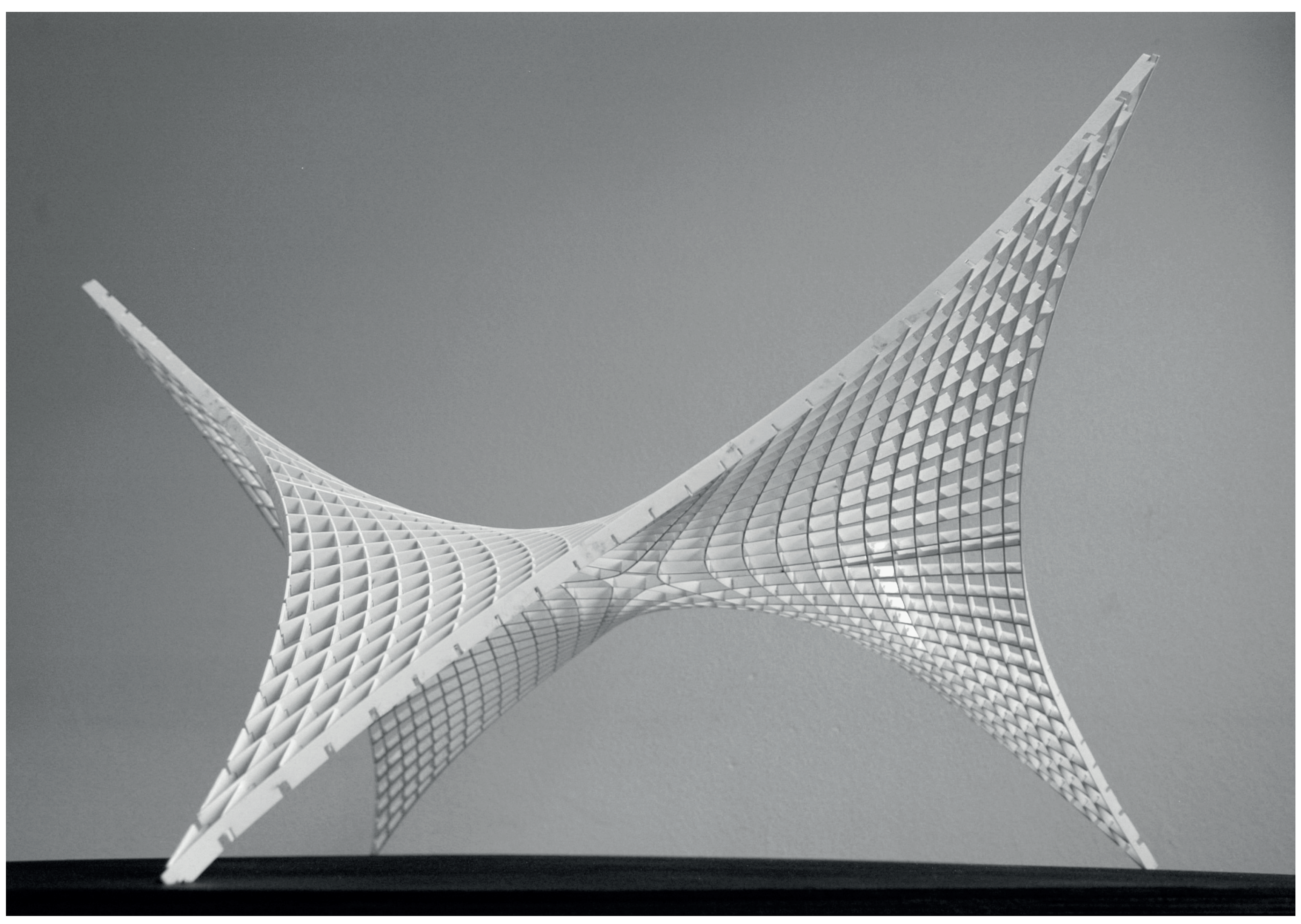

Fig. 2: Model of an anticlastic surface constructed with polystyrol strips, which stand orthogonal to the surface and run along asymptotic lines. All elements can be unrolled as straight strips. Modell: Jan-Ove Reindl & Eike Schling; Foto: Magdalena Jooß

Asymptotic Gridshell

The Asymptotic Gridshell is a design proposal of a pavilion for the Structural Membranes Conference 2017 in Munich (Fig.4). The design takes a clipping of a repetitive, cubic **Schwarz D minimal surface** (Fig. 3), to generate an expressive sculptural space. The support structure follows a curve network of asymptotic lines. All elements can be constructed out of **straight strips with orthogonal nodes** (Fig.5). Future research will investigate material use, structural performance and assembly methods for this new type of gridshell.

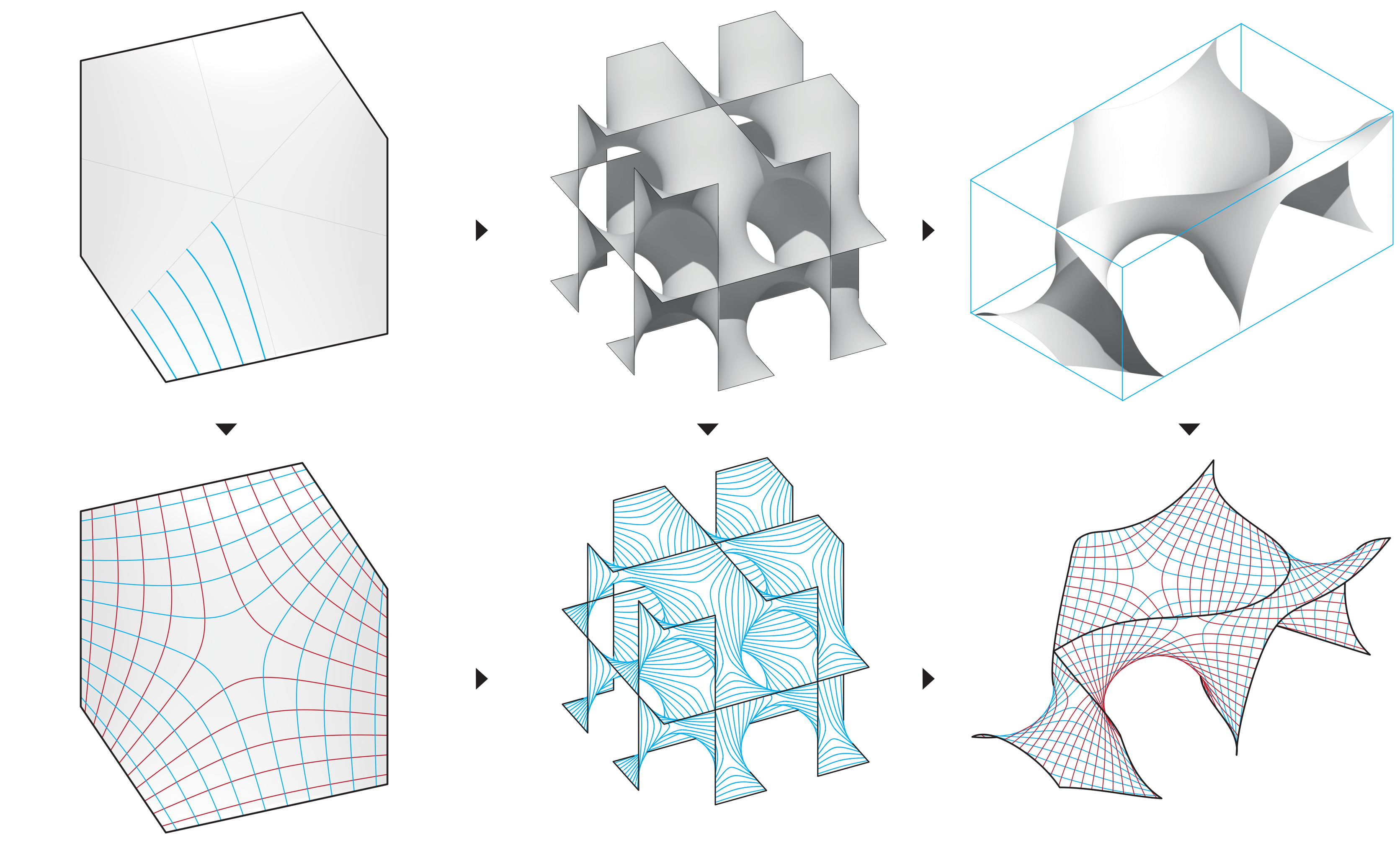

Fig. 3: Design Process: *Left*: A minimal Surface inscribed in 6 edges of a cubic cell. An asymptotic curve network can be constructed from only 5 individual elements; *Middle*: The Schwarz D surface is assembled from multiple cubic cells. *Right*: The design surface is a clipping of this Schwarz D surface.

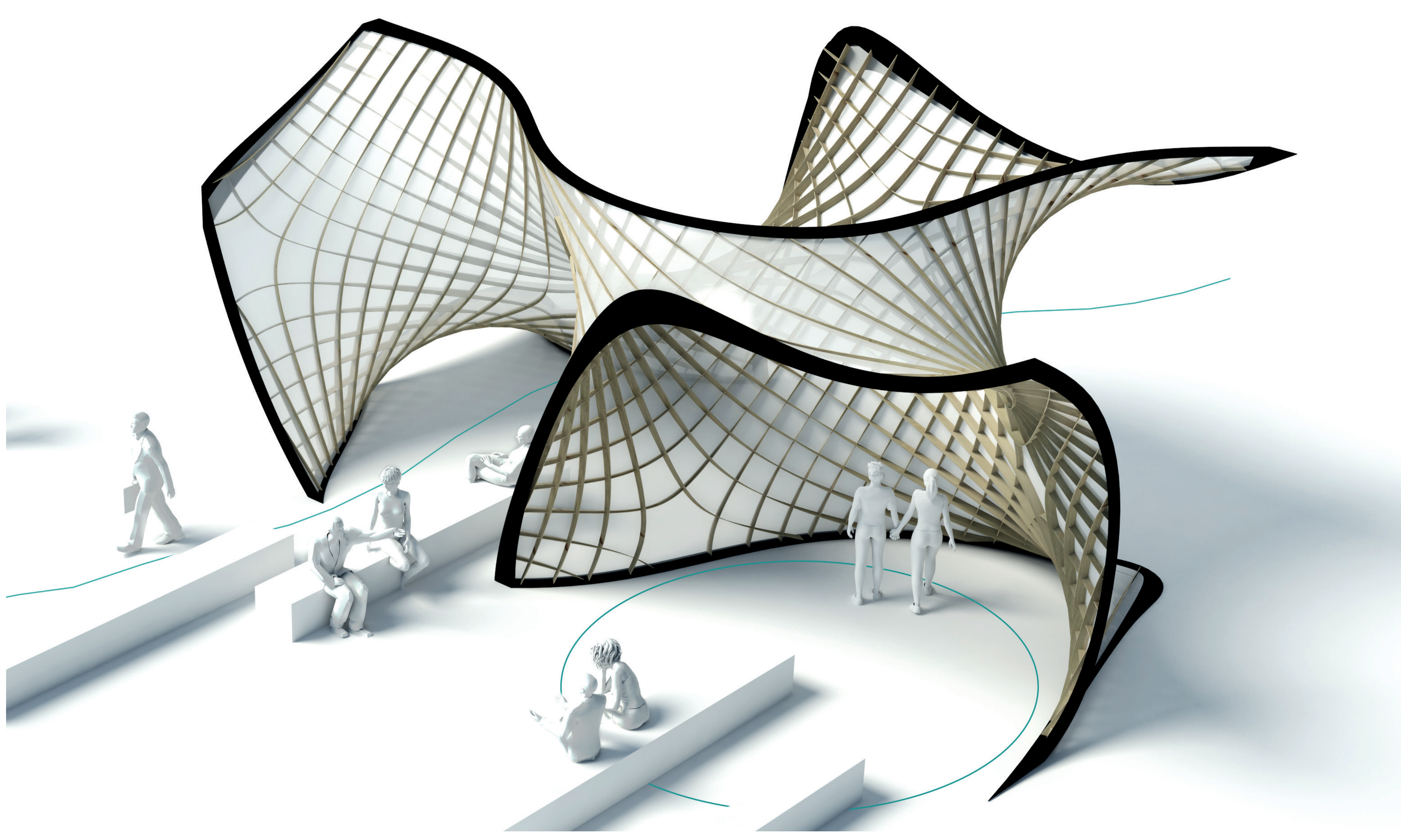

Fig. 4: Design proposal for an Asymptotic Gridshell for the Structural Membranes Conference 2017 in Munich.
Design & Visualisation: Denis Hitrec

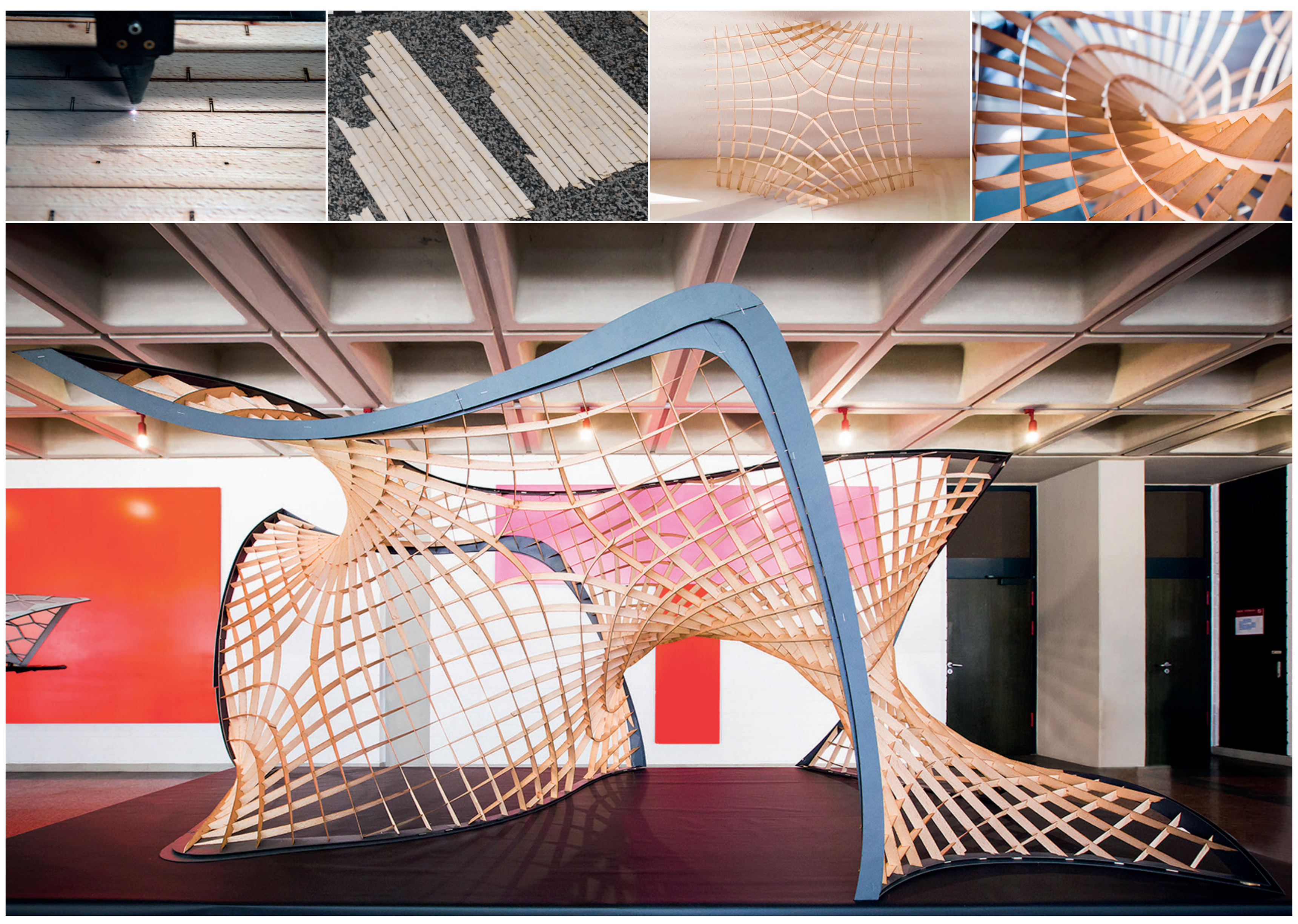

Fig. 5: Prototype model at scale 1:5. A network of asymptotic lines on a clipping of a minimal Schwarz D surface. The support structure was constructed from straight strips of beech veneer. All joints are identical and orthogonal. Model: Denis Hitrec; Foto: Magdalena Jooß