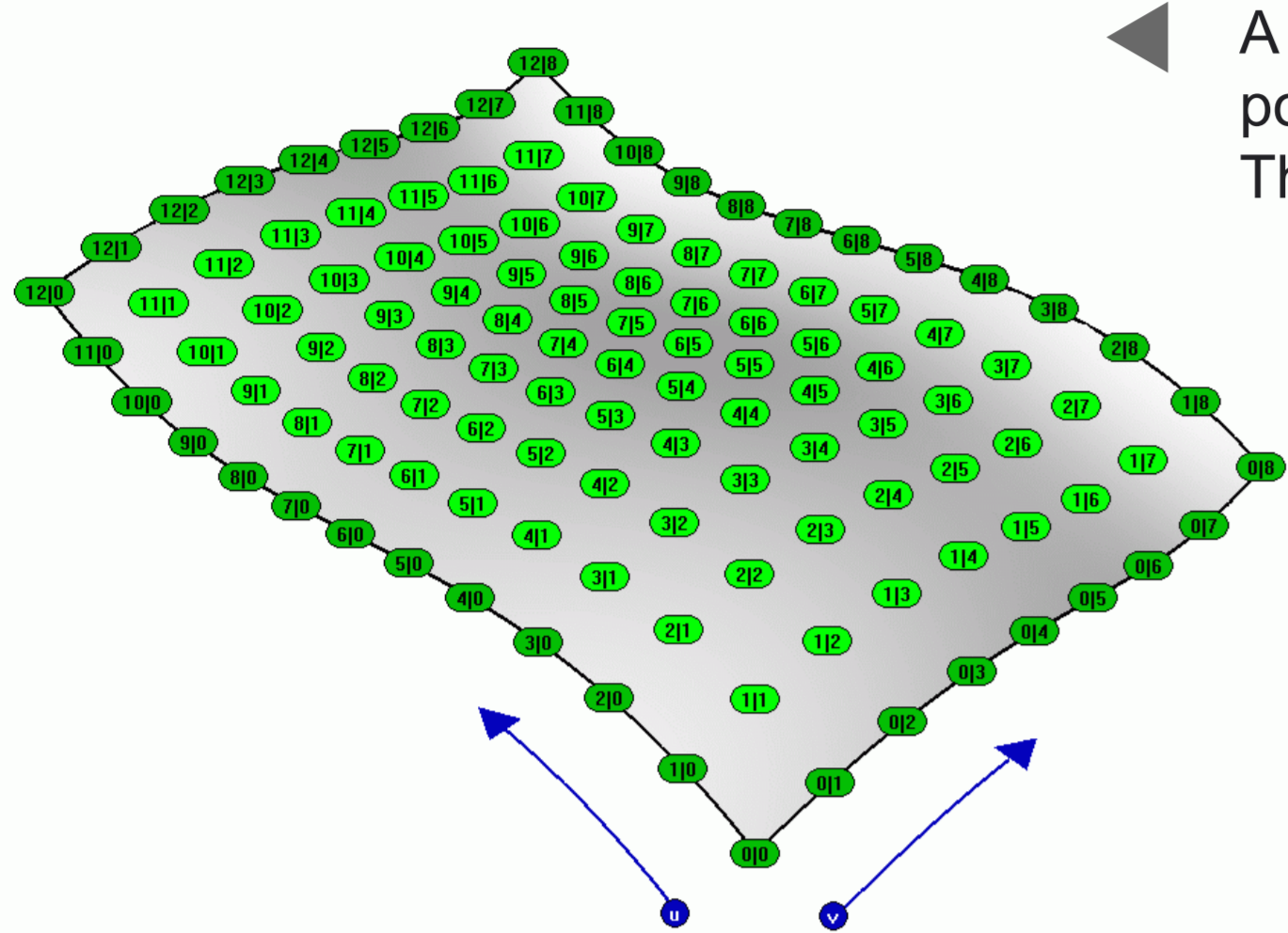# Beyond Isocurves

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Part 1: Point grids on trimmed NURBS surfaces

A popular way to create three-dimensional structures following a given surface is to populate the surface with parametric modules using the surface's u/v coordinate system. This method is fairly simple as long as the surface is an untrimmed NURBS surface.

However, trimming does not affect a surface's u/v parameterization. Contrariwise, the parameters are used to cut the surface along defined curves and the original surface is preserved. That is why trimmed surfaces can easily be untrimmed again.
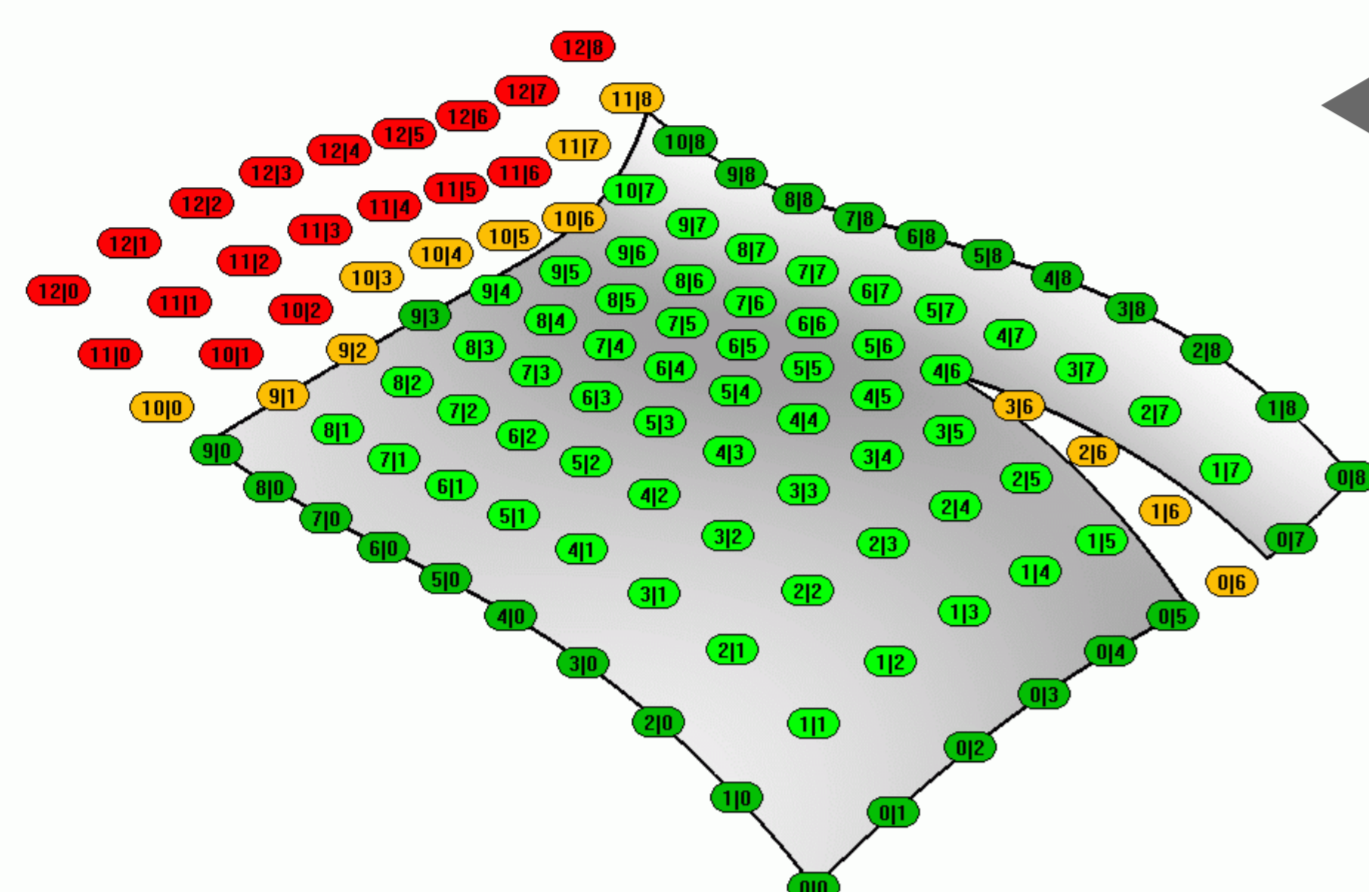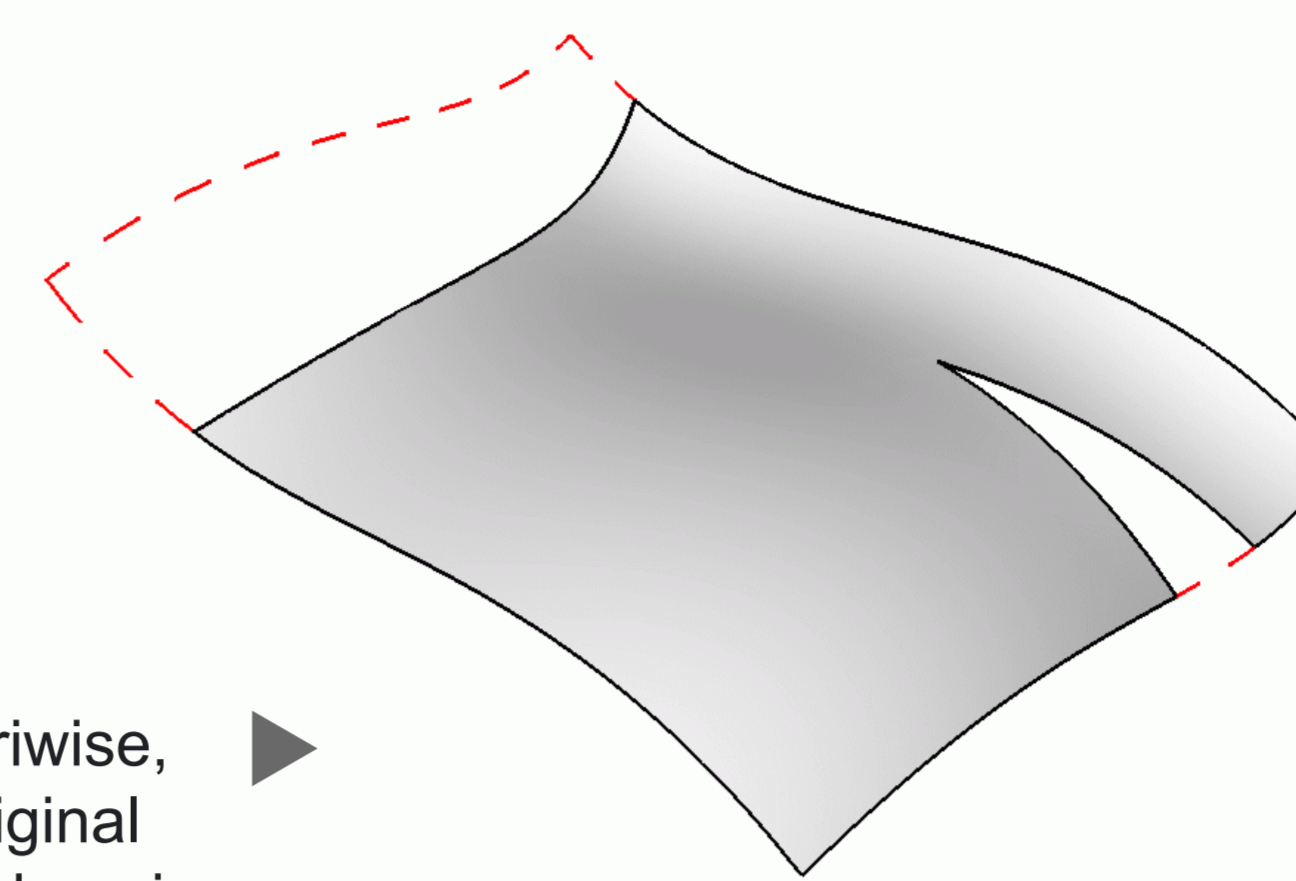
So if above method is applied to a trimmed surface, the points will still resemble the surface's untrimmed version. It is however possible to find out which points lie on the trimmed surface.

In a first step all points neighboring the trimmed surface's borders are pushed onto the surface – each point moves to the spot that is closest to its original position. Should there be any points at the target spots, these are pushed further inside the surface.
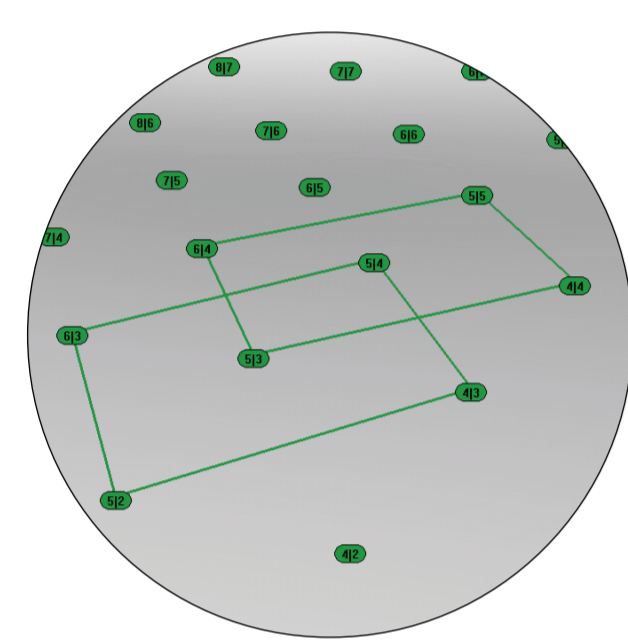
Secondly, a process of dynamic relaxation is run, where every point on the surface tries to be the area centroid of the quadrangle described by its surrounding points. This involves all the points on the surface, so that the whole grid adapts to the new border points from the step before.

Then the process starts over with the points that are now neighboring the surface borders. After some iterations, the result is a homogenous grid resembling the trimmed surface.
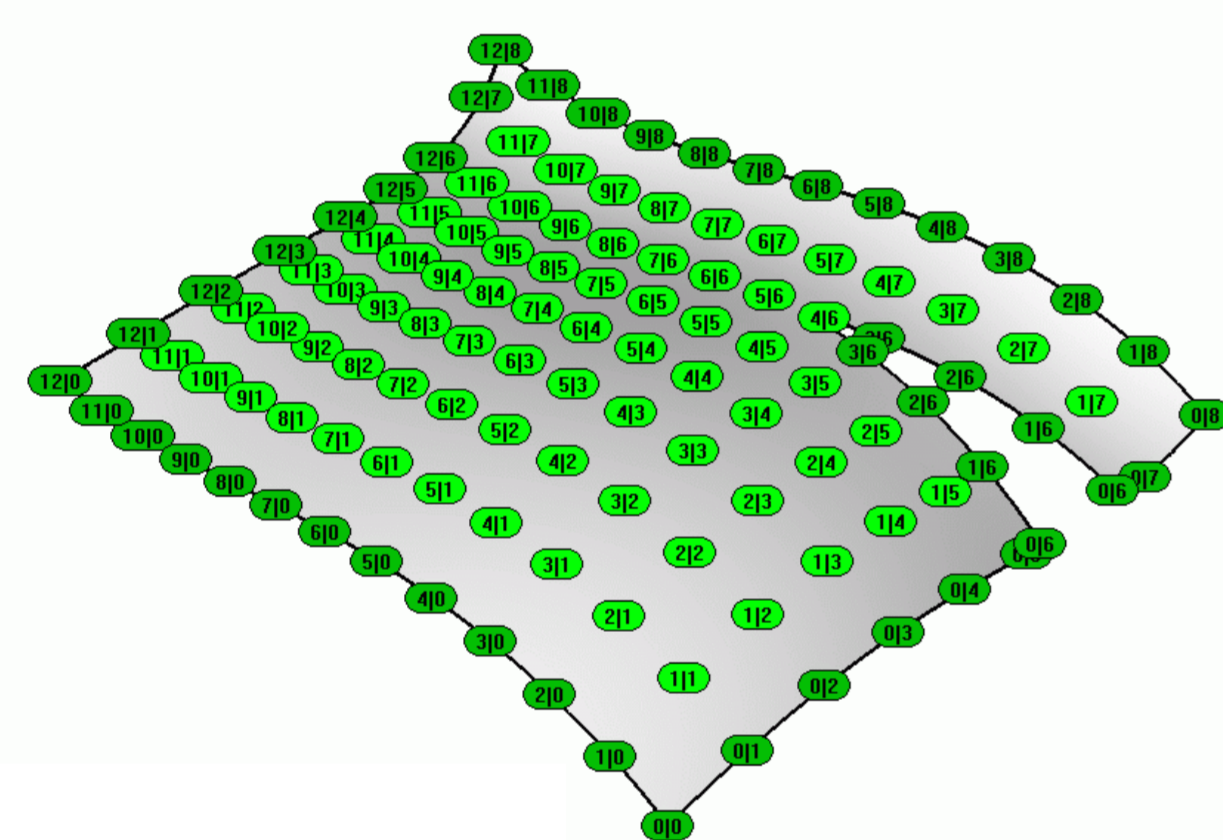
Finally, some points need to be doubled: If there is a gap in the surface between two adjacent points, one of the points needs to have two instances, one on each side of the gap. Only by applying this rule the final grid will have "cuts" where the surface is trimmed. Otherwise such gaps would simply be spanned by later applied geometric modules, being represented only by a slight anomaly in the grid.

Every border point that has a surface gap or hole towards a neighbor point is doubled onto the opposite border. Afterwards another iteration of the surface relaxation process is started.

After this final step, the array is ready to be used e.g. to place geometric modules on the trimmed surface.

## Part 2: Three-dimensional grids on stacks of trimmed NURBS surfaces
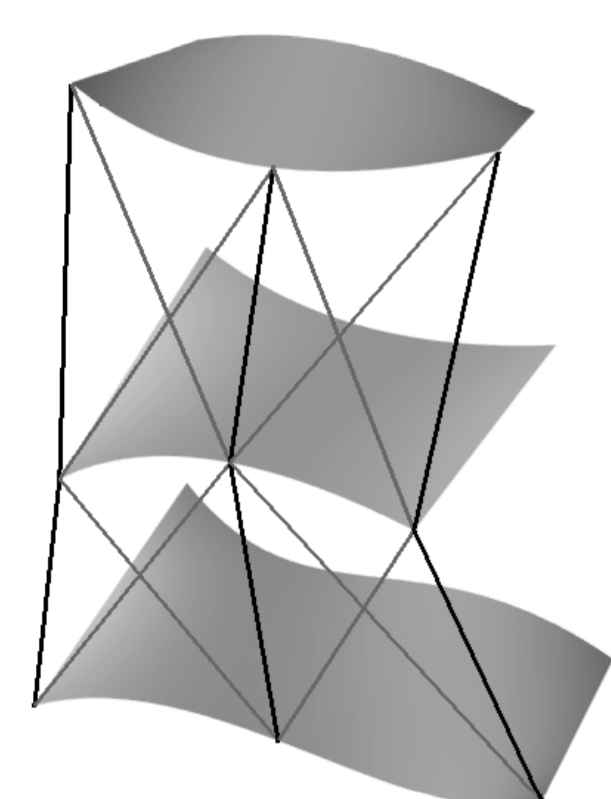
A row of surfaces populated with equally-sized point grids can be regarded as a stack, from which a third dimension can be built by connecting the corresponding points on each surface. But unlike the first two dimensions, the grid's precision is predetermined – the numer of points equals the number of surfaces.

This issue can be solved by connecting the corresponding surface points through interpolated curves and placing an arbitrary number of points along them using the t parameters.
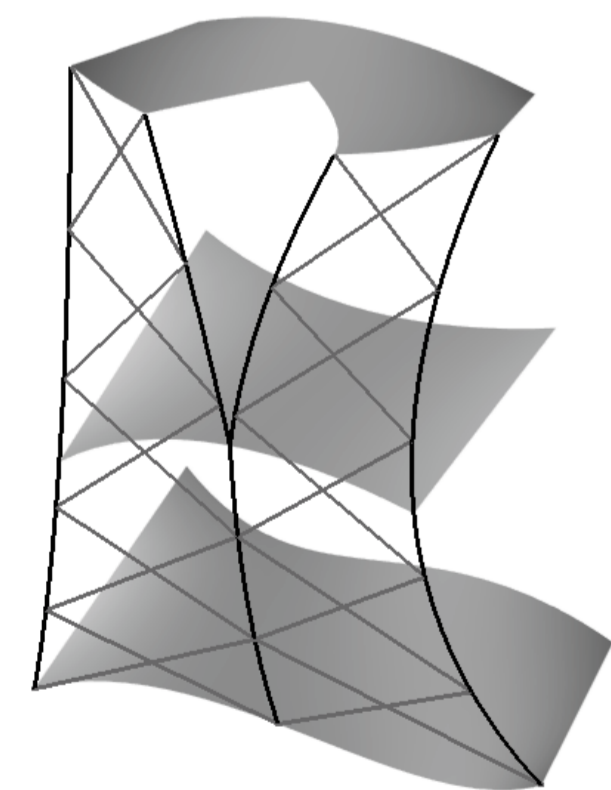
Another problem arises if some of the surfaces have points with multiple instances (due to trimmed gaps, see 1). These multiple points cause the interpolated curves to overlap, leading to deviations between points that should be common.

This issue is solved by segmenting the curves into parts with common points and parts with deviating points. By applying this method in u and v direction, the possibility of gaps and holes in point grids is brought into the third dimension.
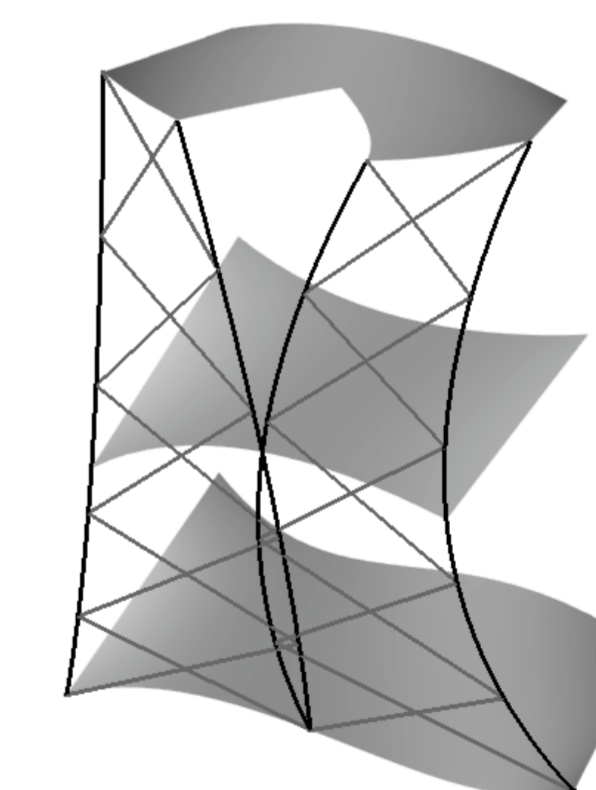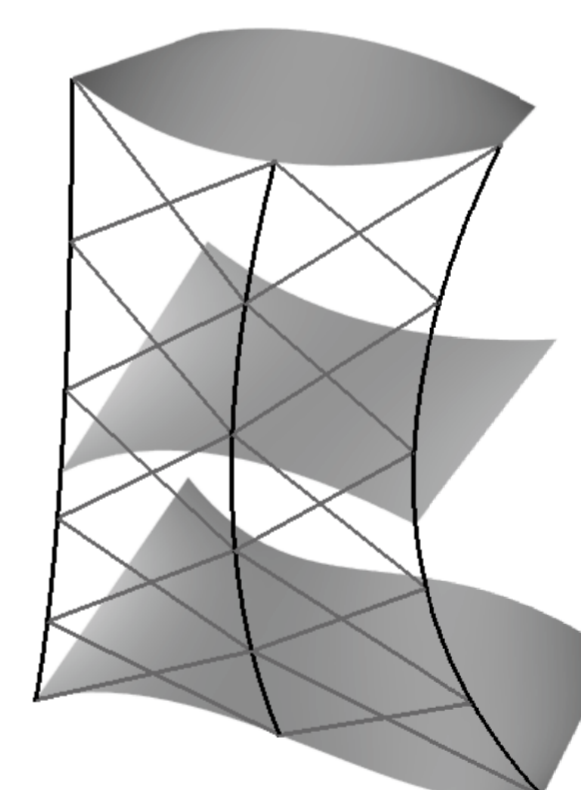
Part 3: Rhino-RSTAB-Interface for script-driven structural dimensioning

During the project a scripting interface between Rhino and the structural analysis application RSTAB was developed. With this interface it is possible to calculate node representations of a structure within RhinoScript environment, so that the results can be used for creation of the final geometry.
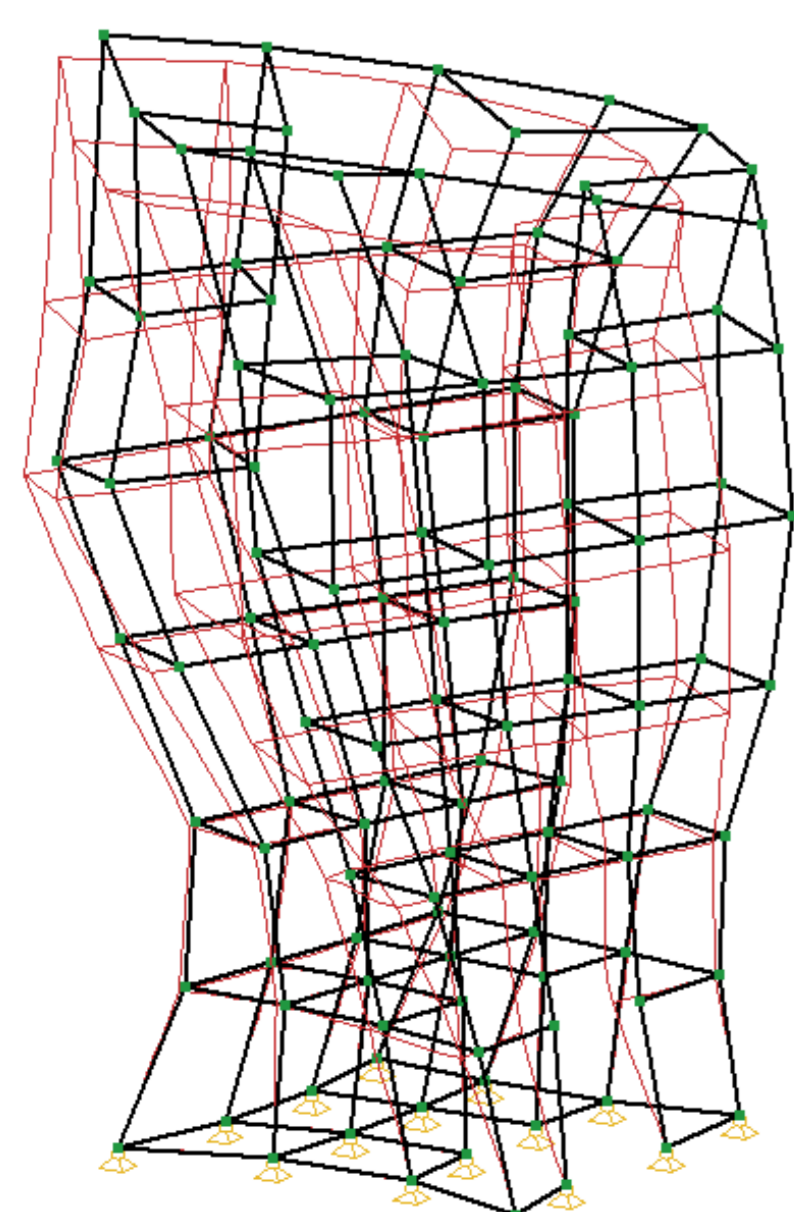
Part 4: Proof of concept – a 3d-printed test object

For the end of term exhibition at the University of Kassel an object consisting of 4x4x7 instances of a simple starlike module running over a stack of six partly trimmed surfaces was created.

The radii of the module connections were constrained by the forces applied to the respective grid members.

The final script was a complete generator containing all steps from surface population to meshing, including the above explained techniques. The object could be printed without any manual editing.