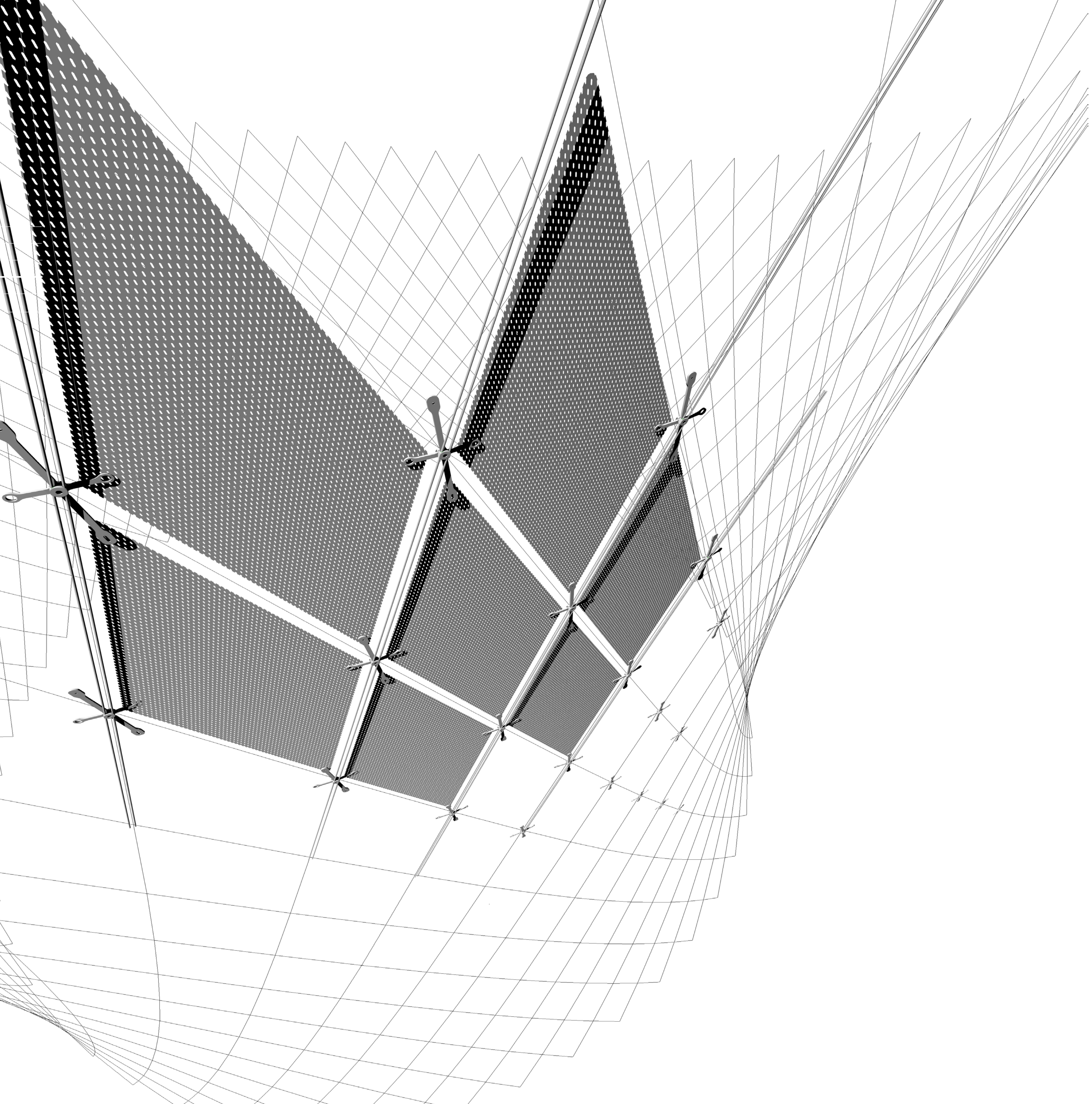


Parametric Modeling with Complex Geometries

When dealing with complex geometries and specialty structures it is critical to develop accurate estimating takeoffs to put together a competitive bid. For the Fulton Street Transit Center proposal an accurate bid for an interior cable-net feature clad with perforated metal panels was generated using nodal coordinate information from the structural engineer to create a 3D model. Over 1100 coordinates, each with and X, Y and Z component, were used as the foundation to automate the generation of the cable-net geometry and extract accurate cable lengths. Beyond estimating the cable lengths, this model served as a study of fabrication and installation means and methods. Moving forward the parametric model can be used for structural analysis to predict the elongation of cable lengths when subject to loading, and used to automatically generate fabrication drawings for the 952 unique rhomboid and triangular perforated metal panels which wrap the net geometry.

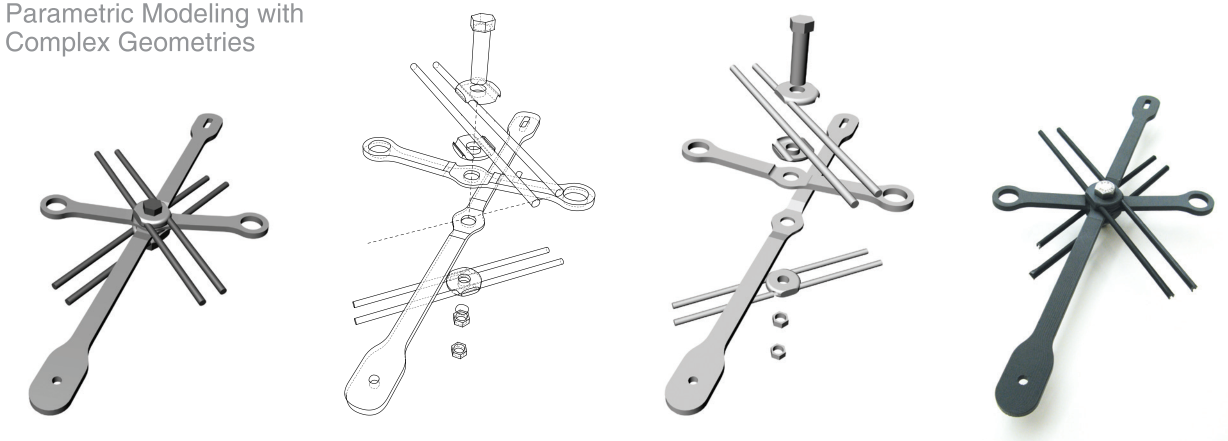


Figure 1. Node fitting views and 3D print (right).

CASE STUDY - FULTON STREET

The Fulton Street Transit Center contains an interior atrium shaped by a double-curved tensioned cable net. Attached to the two-way cable net are 952 unique metal panels cladding the 8524 sf of surface area. There are 17 rows along the height of the net, each with 56 nodes and 56 metal panels. The top and bottom rows consist of triangular panels while all other rows consist of rhomboid shaped panels which are cut planar and then folded in halves to form two triangular facets. The fabrication of these metal panels is a challenging task and therefore we are developing an automatic process for producing fabrication drawings for the metal panels, stainless steel cables and rods.

The structural drawings received during the pre-sale effort included a table of 1056 nodal coordinates to define the stressed geometry of the tensioned cable net. Generating a model specifically rooted in these prescribed coordinates was advantageous in completing an accurate take-off. A text-recognition tool was used to extract the coordinates from the structural drawings. Once the control points were organized within Microsoft Excel maintaining the original naming convention, a process was developed to stream this data into a three-dimensional model.

By developing a custom component within Grasshopper (a parametric tool for Rhino), it was possible to stream the spreadsheet coordinates into the model automatically. After verifying the accuracy of the work-point population the points were used to generate the centerlines for the stainless steel cable members and tension rods which makeup the cable-net. The work-points and centerlines represent the control design geometry, but the finished surface of the metal panels is offset as the result of the component assemblies. The net geometry is offset to develop a finished surface in parallel to the original design surface. Using parametric input, the value can be changed at any point within the design process and all other tasks will update.

The next step takes the offset metal panel mesh, isolates each facet, and locates the bolt hole locations which are offset 5” in each direction for the horizontal armatures and 8” in each direction for the vertical armatures. This task presents challenges in maintaining each bolt hole in plane with its respective panel plane. Once the bolt holes are located on the metal panel boundary geometry, each folded panel must be unfolded from two connected triangle facets into one planar rhomboid shape. Each top facet and the corresponding bolt holes are oriented to be planar in space with its respective lower facet. By getting each folded panel planar it is possible to lay each geometry flat within the workspace to generate a dimensioned drawing for fabrication. At this point the fabrication drawings for the most varied elements – the perforated folded metal panels – is automated based on the original X, Y, Z coordinates without ever manually drawing a line. Having adjustable input variables allow the entire workflow to be designed without fearing what would happen should a design parameter change. The parametric definitions allow the design to flex and adjust on demand.

The parametric model does not die once fabrication drawings are issued. In fact it is transferred into a structural analysis tool to predict elongation characteristics and installation sequencing of the cable net. The simple format of the Excel spreadsheet can be paired with incoming survey data from the field to verify tolerance, and even adjust fabrication drawings to the as-built net geometry.

CONCLUSION

Dealing with a complex form and the goals of automating part generation can be challenging. In the case of this doubly-curved shell there is a complex logic to the form which must be understood in addition to the logic of the automation routines. Developing such tools tends to rely on intense up-front efforts to beta test and trouble-shoot definitions and routines, but are extremely adaptable to unforeseen changes or applications. The Studio continues to experiment with various parametric tools to find appropriate applications within Enclos’ workflow, as well as understand the mediums for design which architects and engineers are generating their forms.

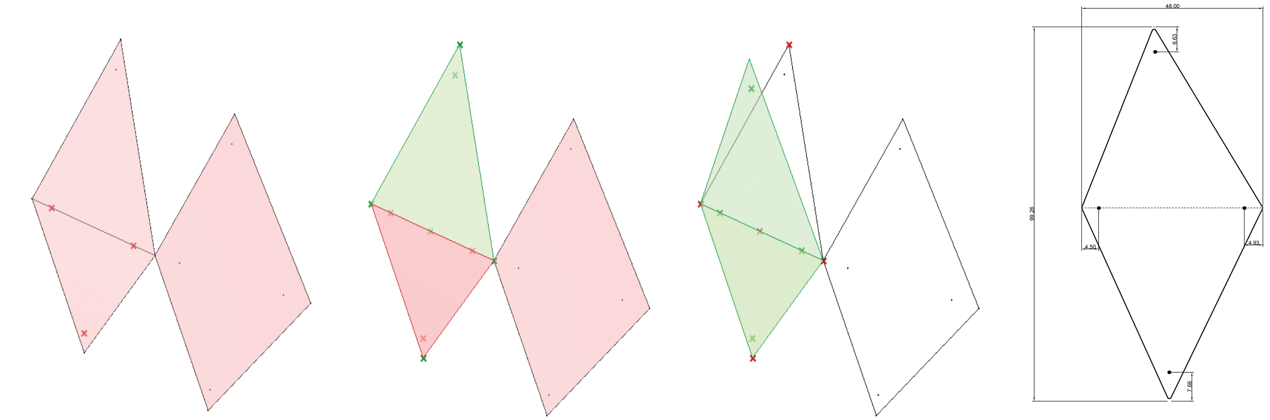
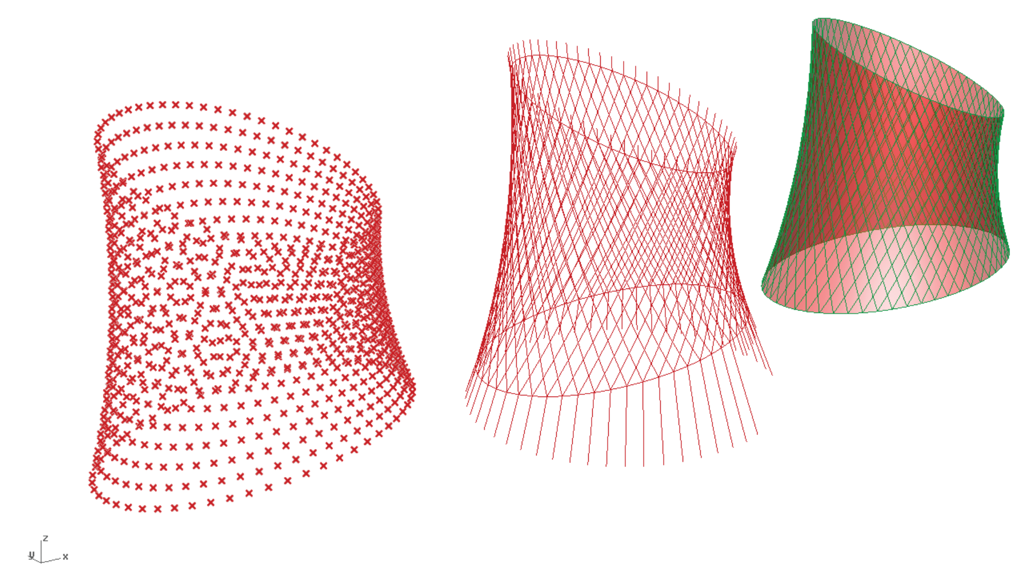


Figure 2. Metal panel deconstruction: subdivided quad into two triangles (left), locate bolt holes, orient top face planar to bottom, and orient for fabrication (right).



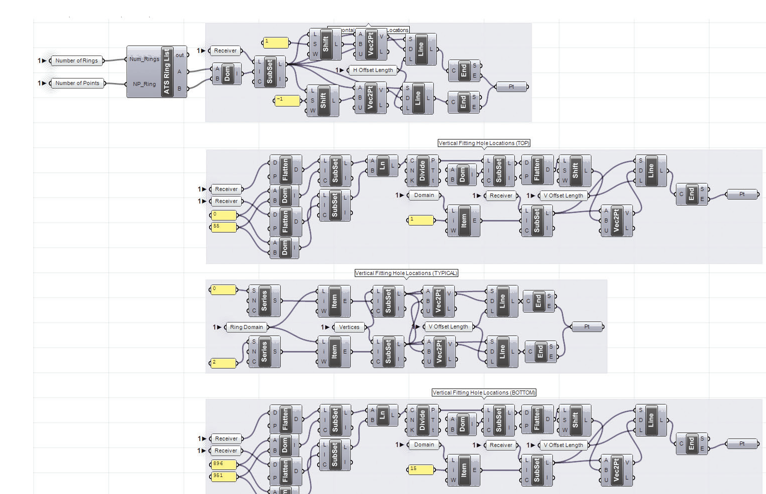


Figure 3 (middle). Sequence of automatic form generation from known node coordinates: work-point population, member centerline deduction, and mesh (metal panels) generation.

Figure 4 (bottom). Excerpt from parametric Grasshopper definition. This section shows the routine for inheriting the work-points and finding the offset horizontal and vertical bolt holes at each node in plane with each respective facet.

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