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# Design of freeform gridshell structures – Simplifying the parametric workflow

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## Abstract

Freeform structures can provide both aesthetically interesting and material efficient solutions but are considered a demanding task for both structural design, manufacturing and architectural design. A free form surface is therefore rationalized into something more buildable like the gridshell. However, a digital design process with freeform geometry can be a complex and confusing task. By defining a gridshell as *nodes*(joints) and *elements*(members), we can set up a parametric workflow that handles the complexity in design and analysis. Optimization and rationalization of shape, topology, and cross-section are studied real-time, giving the designer confidence and design-freedom. This paper explains a parametric workflow for designing freeform gridshells. Through the design and construction of a timber gridshell pavilion with 3D printed nylon nodes, we discovered important elements of the parametric design process of freeform gridshells.

**Keywords:** Free form; shell structure; surface structures; reticulated; gridshell; parametric design; parametric; aluminum; timber; 3D print.

## 1. Introduction

Freeform structures can provide both aesthetically interesting and material efficient solutions. Freeform structures can be defined as a shape that is neither a non-structural irregular shape (blob) or a mathematically form-found shape.

Freeform structures are considered a demanding task regarding structural engineering. The manufacturing of free form structures could demand both complex manufacturing tools and substantial geometry rationalization. Simultaneously, architectural design and geometric description of free form structures could require advanced design knowledge. A common simplification is to construct the free form structure with nodes (joints) and elements (members), also called a gridshell or reticulated surface structure.

Working with free form gridshells, one approach can be to make project-specific software that generates and calculates geometry [1]. One of the main manufacturers and engineers of reticulated surface structures, the German company MERO®, started developing their own tube/node constructions and design methods in the 1930s. This paper aims for a general approach that would apply to all kinds of gridshells. With the help of parametric modelling software, node designs can now quite easily be developed and analysed.

Renowned engineer Jan Knippers describes the recent development in glazed grid shells by emphasizing the point of not losing the architectural vision [2]. Knippers states that the actual limitations today lay on neither the analysis nor the fabrication. Both the structural design and architectural geometry are controlled and calculated with one flexible parametric model. This

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