Inventory Constrained Funicular Modelling

Combining Funicular Geometry Optimisation with a Material Inventory Constraint

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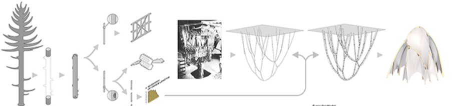
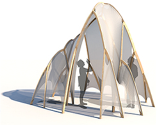


Material Constraint.
An inventory of unique short timber lengths is generated from naturally occuring tree branch density.

Funicular Model:
Geometry remains funicular but is also adapted to the inventory of unique short timber lengths, enabling dual optimisation.



Abstract

*This pavilion was designed and fabricated using a digital form finding model that combines the generation of **funicular geometry** with a material **inventory constraint**. The form finding model is a design tool that allows the exploration of structural form whilst simultaneously satisfying two rationalisation criteria. It maintains an equilibrated structure derived from funicular geometry; and optimally assigns an inventory of parts containing naturally occurring dimensional variation. The combined goal for the design outcome is to achieve material efficiency through both structurally rational form and minimization of material waste.*

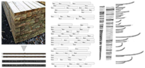
The material chosen for the inventory was utility-grade sawn timber[1], being lightweight but with naturally occurring structural defects. An otherwise non-structural material, it will readily yield usable short lengths of structural members once the defects are removed, and in doing so, generate a unique inventory of random short members. These are well suited to articulated structures, which, by employing an inverted funicular geometry, only incur axial stresses and can employ simple (non-moment resisting) timber connections.

Project Description

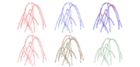
Gaudi's use of the funicular or 'hanging chain' model was a sophisticated form finding tool for rationalising structural geometry and optimising material utilisation. This project proposes to combine digital funicular modelling with a computational part assignment heuristic, where structural elements sourced from a unique material inventory are assigned to their optimal location within a funicular structure.

At the saw mill, scans are taken of each member's material properties and a dataset produced that locates each defect. Via a MATLAB translation of the scan data that plots the timber made available after defects are removed, an inventory of remaining short length structural parts is generated. For structural typologies such as funicular arches that inherently utilise short members, and also of varying length, this inventory is of potential value.

The modelling process begins with the digital generation of a funicular 'base geometry' of interconnected arches through dynamic relaxation. The arches generated within this are then assessed against the inventory of actual lengths via a part assignment heuristic based on a minimum curvature tangent differential, and a 'best fit' permutation of inventory parts is mapped to the geometry.



Timber scanning; generation of inventory; and assignment of parts to inital funicular arch geometry



Second iteration of funicular geometry relaxation, now targeting aggregate part lengths

The resultant aggregate lengths of the mapped inventory parts are then used to establish precise target length criteria, which are enforced in a second iteration of the dynamic relaxation, where the 'base geometry' is re-relaxed to meet the target lengths, but always remaining funicular in profile.

The re-relaxed funicular geometry is then translated into solid curved arch segments and nodes, and a minimal surface is digitally 'stretched' between the arches to define the interior space, the exterior volume, and the entries to the pavilion. Toolpath geometries for the timber members, nodes and fabric shapes are then output for CNC machining and sewing.

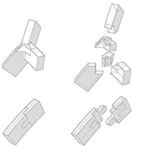
Via this dual process combining form finding in the funicular model with material optimisation through an inventory constraint, the structure achieves optimal material deployment, transforms an undervalued timber resource, and increases the recovery of structural grade timber from plantations.

CNC machined lapped dovetail joints

Stretching the fabric over the structure

Material Utilisation:
55 kg of timber in 2 crates, 2 kg of fabric plus tools, adhesive, and incidentals max 10kg in third crate

1 - Timber sourced is Australian plantation grown pine, 'utility-grade' refers to members that do not meet structural grading standard due to the presence of frequent defects.



Joint Typology:
3 way compound rabbet joint and in-plane lapped dovetail joint

Fabric connection detail