Trihexagonal Kagome Pattern Gridshell

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Abstract

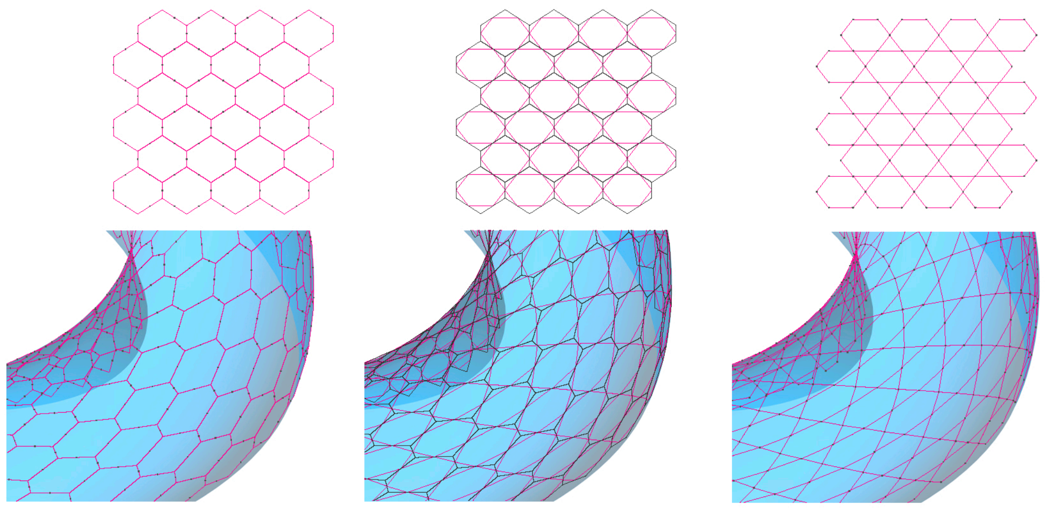
The object of this poster is to comprehend, evaluate and re-interpret the structural system applied in Shigeru Ban's Pompidou Metz's glu-lam timber canopy. After describing the algorithm behind the design of the trihexagonal grid double curved surface, we will attempt its implementation to another, more complex doubly-curved surface, we will propose alternatives explaining each solution's advantages over the other and compare their efficiency in terms of production optimization.

1. Introduction

The interpretation of a complex double curved surface in a grid pattern is borrowing a traditional lattice production technique, as is weaving in basketry. The surface subdivision pattern chosen in the case of the canopy of Shigeru Ban's Pompidou Metz is a trihexagonal one, and had to be adapted to a double-layered superposition of same-direction beams rather than weaving them, due to the special characteristics of the building in question that required a pre-fabricated glue laminated beams. We are about to examine the possible adaptations of the initial intention in cases of surfaces with wider ranges of curvatures and smaller spans.

2. Background

The practice of basketry, apart from offering a topological map of a surface's structure, is also a perfect example of an equilibrium auto-rigidised form, with no need for glue or binding. Its application depends highly on material elasticity and the formation of a tension shell.

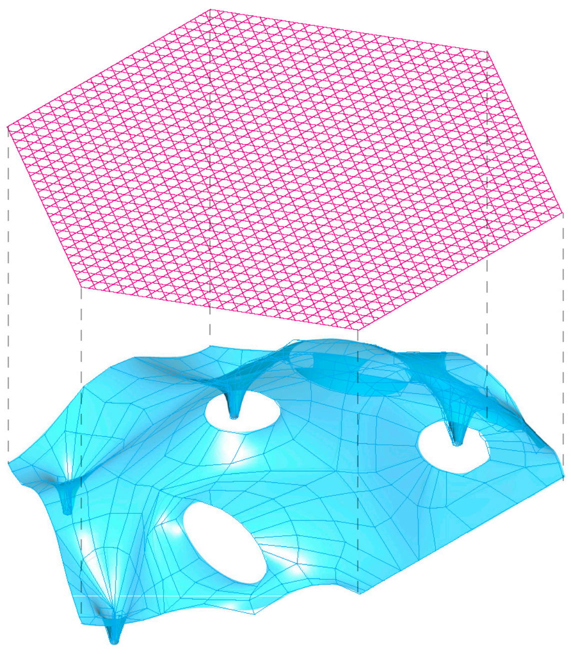


However, scaling-up to larger building spans where the scale of the structural cloth is increased to a net, another approach is to be applied, the one reffered to as surface mapping. We no longer treat the surface as a continuum textile material, but as a grid.

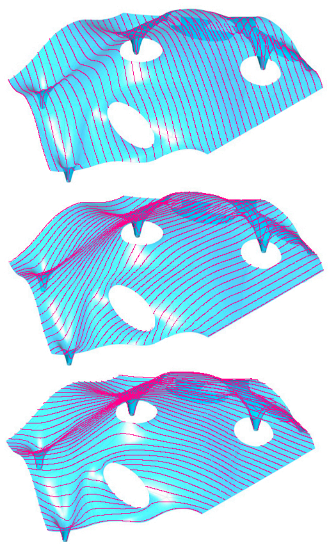
Generally, the trihexagonal grid emerges from the dual polygon structure of any triangular mesh syrface, when joining the midpoint of each polygon side with the consecutive one.

3. Casestudy

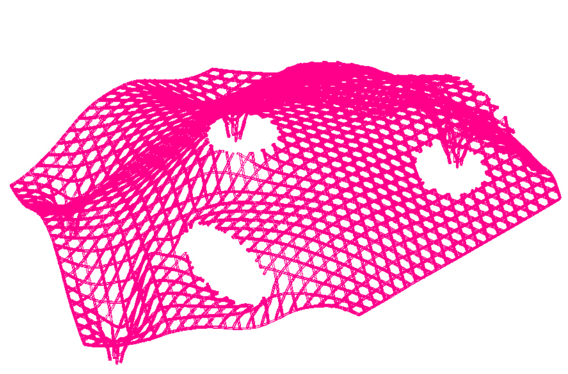
Building:: Centre Metz Pompidou, Architect: Shigeru Ban Architects Europe, and Jean de Gastines Architectes, Picture by Didier Boy de la Tour



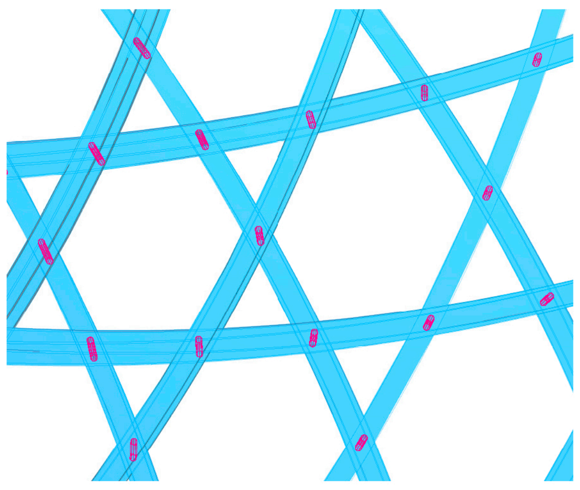
1. Kagome lattice application to surface's flat projection. In the case of Pompidou Metz, a hexagonal flat surface is the boundary of the tri-hex grid.



2. Vertical projection of grid on surface. The three directions of curves are vertically projected onto the surface designed.

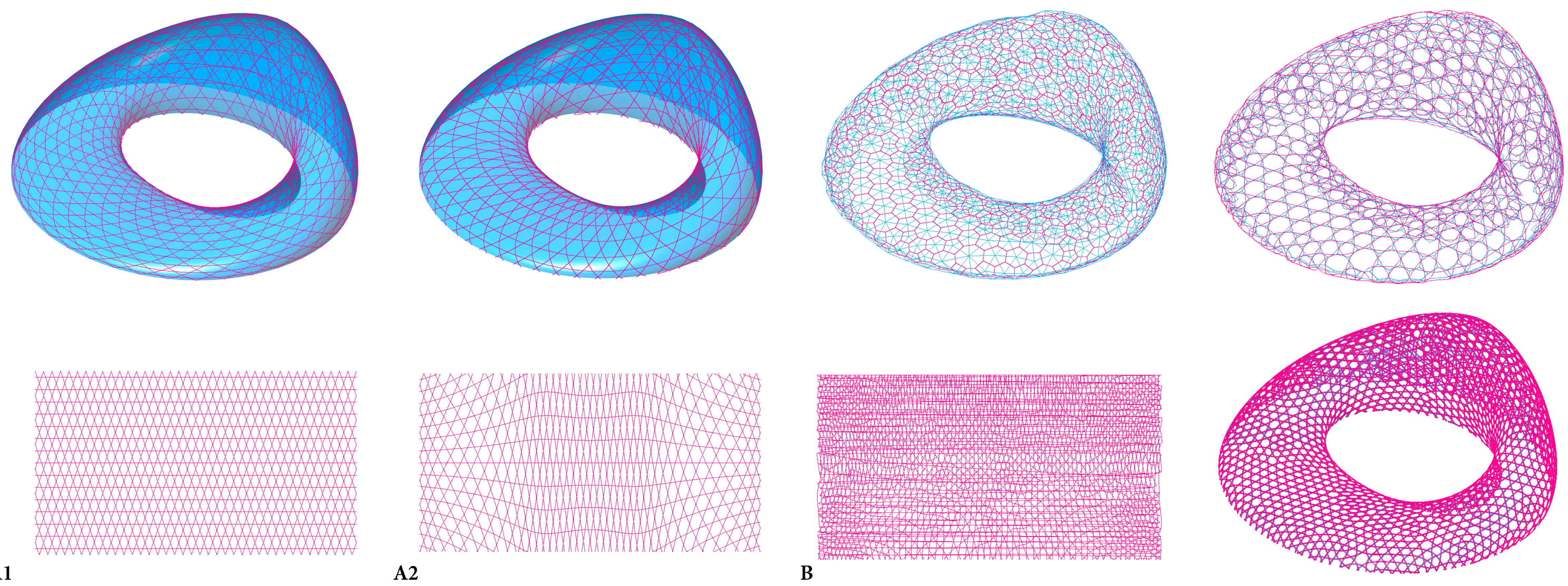


3. Superposition of layers
Each direction-group is projected on consecutive offsets of the initial surface.



4. Intersection Bolts and Shear Blocks
Two pairs of beams intersect at nodes that are translated into hexagonal bolts vertical to the surface.

4. Adaptation strategy



A1

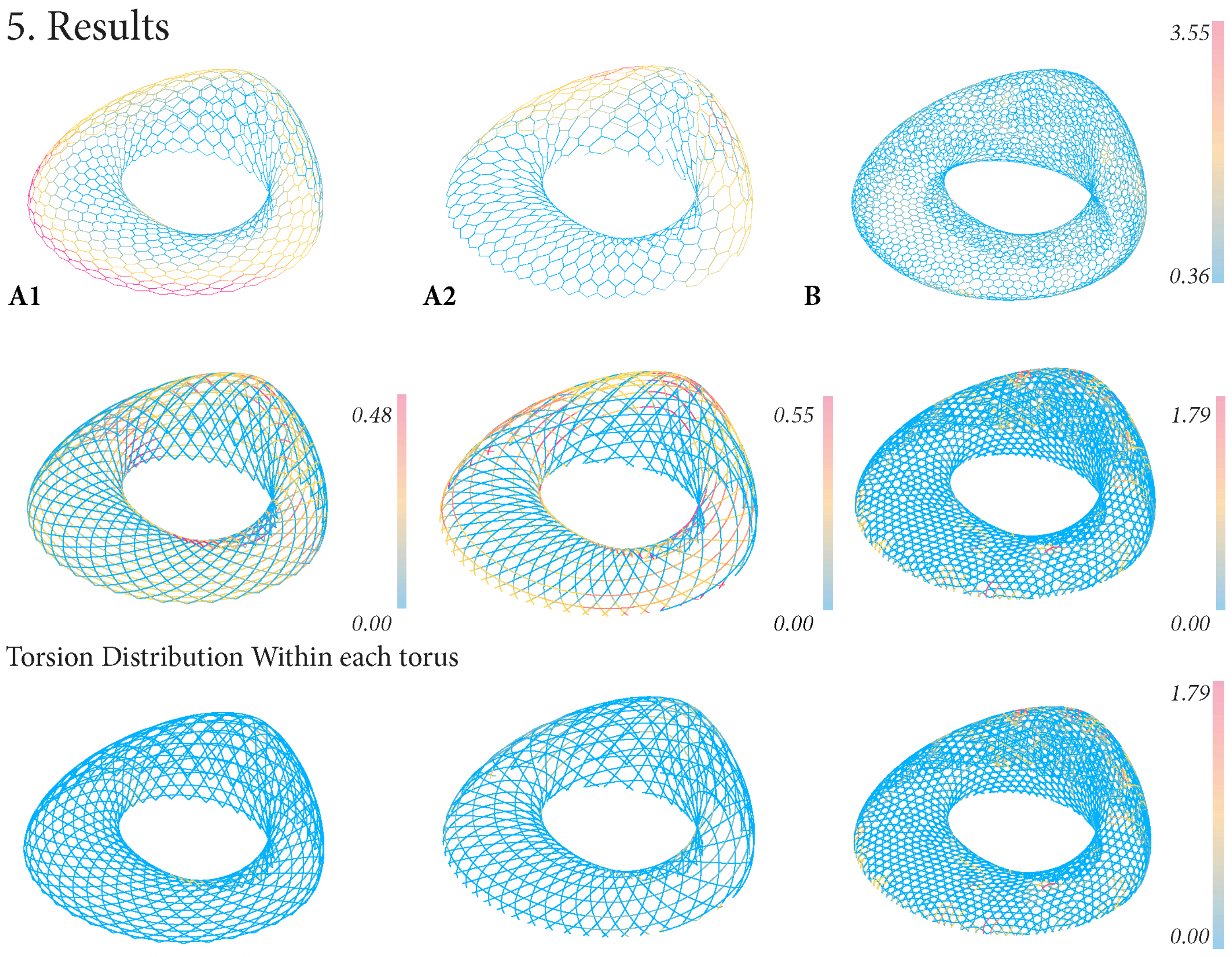
A2

B

A. UV mapping of lattice from flat surface
[1] Hexagonal grid applied to flat, orthogonal surface. Mapping to toroidal surface by direction, Kagome formation and offset layering. Mapped pattern: isometric.
[2] The above steps repeated, only in this case the hexagon grid is trimmed by a surface scaled by the U section curve lengths of the toroidal surface. Mapped pattern: distorted.

B. Topology based mesh approximation
We propose a mesh approximation of the torus surface, of same-length edges.
The application of the above process on polygonal grids on the dual mesh, produces a polygonal segmented lattice. Out of the joint of these segments we come up with continuous beams.
We are able to unwrap the pattern of beams on a plane surface.

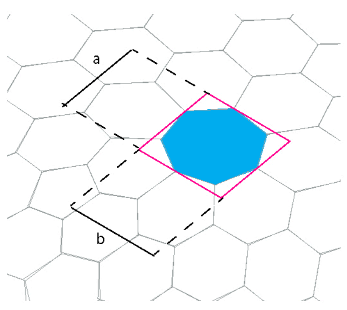
5. Results

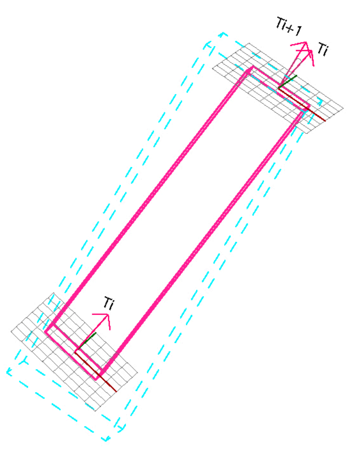


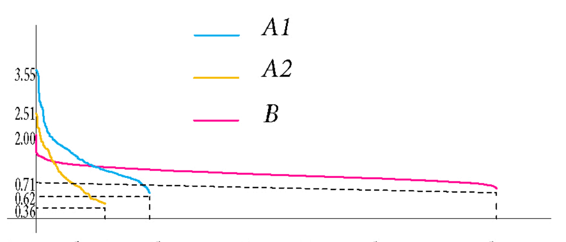
Torsion Distribution Within each torus

Torsion Angle rates Comparison between the three models

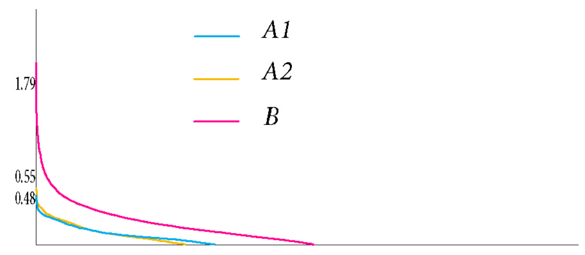
A1 A2 B







Panel size dispersion: In order to evaluate the efficiency of the alternatives proposed above, we must take into consideration production processes of where standardization is desired. For the panelling of the grid surface, we measure the range of proportions of polygons.



Beam Torsion _ Fibre direction angle
Considering the glu-lam member fabrication by CNC milling, we calculate the angle of the curve's tangent with the fibre direction of each member at consequent sections, to estimate the amount of material that shall be milled and the amount of machining operations.

6. Conclusions

The vertical projection system applied in Pompidou Metz is only efficient in surfaces where the ratio area-projection surface area is near 1. Most efficient alternatives are the ones where the trihexagonal grid derives from inherent characteristics of the surface, in proportions or topology.
In further, future research we could examine the relation between geodesical curves as a base for the Kagome lattice, in order to avoid any material waste during fabrication.

7. References

1. Alison G. Martin, *A Basketmaker's Approach to Structural Morphology*, Proceedings of the International Association for Shell and Spatial Structures (IASS) Symposium 2015
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3. John Wiley & Sons Ltd, *Woven Surface and Form, Arup AGU, AD Architextiles, Vol. 76, November/December 2006.*