FlexMaps Pavilion: a twisted arc made of mesostructured flat flexible panels

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Abstract
Bending-active structures produce efficiently complex curved shapes made of flat panels. Their systematic deformation lies in the accurate selection of materials with suitable elastic properties (i.e. allowable linear strength and bending stiffness). This project aims at realizing complex doubly-curved 3D surfaces using flat panels with tailored mechanical properties. These panels, called FlexMaps, are optimized such that, once they are bent and assembled, the resulting static equilibrium configuration matches a desired input 3D shape. Instead of designing the elastic properties of a continuous panel, in the FlexMap panel the stiffness is controlled locally by varying spiraling geometric mesostructures, which are optimized in size and shape to match the global curvature (i.e. bending requests) of the target shape. As a result with this approach it is possible to obtain desired mechanical properties without changing the material but only by acting on the geometric parameters of spirals [1]; additionally, also stiff materials can be used.
The design pipeline starts from a quad mesh, which defines the edge size and the total amount of spirals. Every quad embeds one spiral. Then, an optimization algorithm tunes the geometry of the spirals by using a simplified pre-computed rod model. This rod model is derived from a non-linear regression algorithm which approximates the non-linear behavior of solid FEM spiral models subject to hundreds of load combinations.
This pipeline is applied to the project of a lightweight pavilion named *FlexMaps Pavilion*, which is a single-layer piecewise twisted arc that fits a bounding box of 3.90x3.96x3.25 meters. The FlexMaps Pavilion allows for easy fabrication and assembly procedures. Commonly, bending-active structures need rotational degrees of freedom in the assembly phase (i.e., hinged edges or pinned joints) or inflation loading, while in the FlexMaps Pavilion each panel lays flat in the rest configuration and its final shape results from internal elastic forces that arise when connecting, progressively, the spiraling elements. This operation requires only limited bending energy.

References

[1] L. Malomo, J. Pérez, E. Iarussi, N. Pietroni, E. Miguel, P. Cignoni, and B. Bickel, FlexMaps: computational design of flat flexible shells for shaping 3D objects, *ACM Trans. Graph.* 37, 6, Article 241, 2018. DOI: https://doi.org/10.1145/3272127.3275076