BATS - A software for the parametric design of membrane structures

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ABSTRACT

This work presents a novel software for the parametric design of tensile structures. BATS (Basic Analysis of Tensile Structures), currently under development at the University of São Paulo, is a Grasshopper plugin that enables the parametric definition of cable and membrane structures, allowing for a quick and consistent parametric design, including the traditional phases of form-finding, patterning, flattening and non-linear structural analysis. The software consists in an application module in developed in C#, within Grasshopper's Visual Programming interface, and a numerical module developed in C++ for performance purposes. Through a sequence of Grasshopper components, it was possible to define a linear workflow throughout the whole structural design process, where any change in parameters propagates seamlessly to the subsequent steps.

BATS inherits the implementation of Argyris membrane element available in SATS [1] for geometrically non-linear formulations, and also implements an alternative isoparametric finite element formulation. Form-finding is performed by the Force Density Method (FDM) for cable elements and the Natural Force Density Method (NFDM) [2] for membrane elements. Previous work [3] showed the gains in performance using those methods, compared to other available tools, due to the linear nature of FDM and NFDM, as well as the use of optimized linear solvers. Moreover, since BATS is native to Rhino/Grasshopper, it conveniently inherits other native tools, for instance to find geodesic lines along membrane surfaces and a mesh regeneration algorithm, to accommodate the mesh to defined seam lines and remap the stress/strain fields. Seamless integration with other Grasshopper native tools, such as genetic algorithms, allows for quick and robust exploration of the parametric space, as well as parametric optimization. A beta version of BATS can be downloaded from *www.food4rhino.com/en/app/bats*.

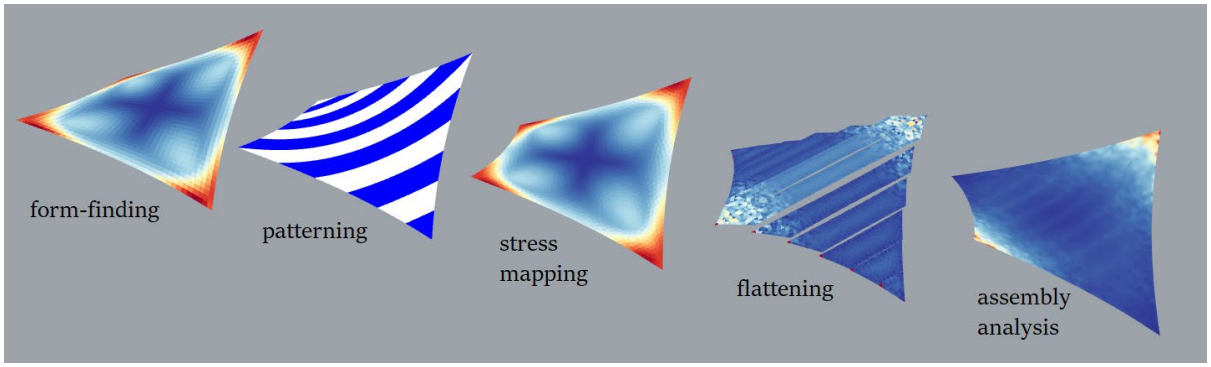

Figure 1 – Different stages of the design of a saddle membrane in BATS

REFERENCES

[1] Ruy Marcelo Pauletti, Daniel Mariani Guirardi, Telmo Egmar Camilo Deifeld, "Argyris' Natural Membrane Finite Element Revisited", *STRUCTURAL MEMBRANES 2005 - International Conference on Textile Composites and Inflatable Structures,* CIMNE, Barcelona, 2005 E. Oñate, and B. Kröplin, (Eds).

[2] Ruy Marcelo Pauletti, Paulo Mattos Pimenta, "The natural force density method for the shape finding of taut structures". *Comput. Methods Appl. Mech. Engrg.* **197** (2008) 4419-4428, doi: 10.1016/j.cma.2028.05.017

[3] Márcio S. V. de Souza, Ruy M. O. Pauletti, "An overview of the natural force density method and its implementation on an efficient parametric computational framework", *Curved and Layered Structures* **8** (2021) 47-60, doi: 10.1515/cls-2021-0005