Curved folding with inflatables

Master-level internship (research), could be extended to a PhD

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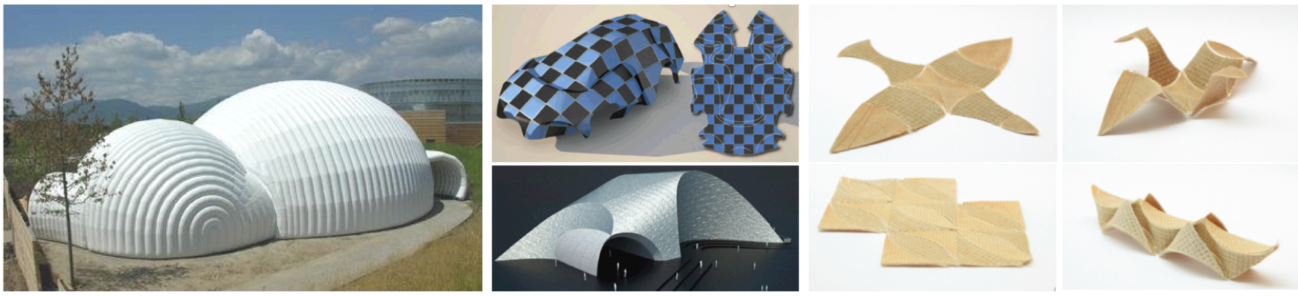

Figure 1: Left: Inflatable architectural structure (fstructure.com). Middle: Digital paper models folded along curved lines [1]. Right: Self-shaping curved folding structures [3].

Context

Inflatable structures have many applications in multiple fields such as architecture, entertainment, robotics and more. They can be used for temporary shelters (Fig.1, left), soft robots, packaging, floating devices, furniture to give a few examples. In practice, most of these structures are made of tubular chambers, which are easy to fabricate and whose mechanical behavior is well understood. However, the high anisotropy in the tubular pattern translates to mechanical anisotropy and limits the space of shapes that can be reproduced. More specifically, since tubes easily bend in one direction only, the structure generally assumes a piecewise developable shape once inflated. This constraint on developability also appears when working with other materials such as paper or some bilayer materials. For these materials, prior work ([1], [3]) has investigated the use of curved folding for expanding the design space of 3D shapes that can be obtained from initially planar sheets of materials (see Figure 1). This project investigates the use of this type of approach with tubular inflatables.

Objectives

The goal of this project is to propose an algorithm to design 3D structures approximating a given target shape by self-folding inflatables structures along curved creases automatically obtained. As a first step, we will adapt the algorithm by Tahouni et al. [3] to the case of inflatables made of parallel tubes. Such inflatables are made of two planar membranes sealed according to parallel lines and are particularly easy to fabricate.

To compute the shape of the inflatables, we will use an in-house C++ simulator tailored to the simulation of such structures. This simulator relies on a finite element method and a convexified membrane model that can robustly handle the large deformations and buckling of the membrane [2].

This internship will give you the opportunity to learn about discrete differential geometry, non linear mechanics and numerical methods for simulation.

If successful, this master's thesis is expected to lead to a PhD thesis on the inverse design of free-from structures made of inflatable structures as part of the ANR project MatAIRialS.

Work environment and requirements

This internship will take place at Inria Grenoble – Rhône-Alpes and will be supervised by Mélina Skouras (melina.skouras@inria.fr, `http://imagine.inrialpes.fr/people/mskouras/index.htm`).

The candidate should have strong programming and mathematical skills, and ideally knowledge in computer graphics, and have a taste for numerical simulation and geometry.

References

[1] Martin Kilian, Simon Flöry, Zhonggui Chen, Niloy J. Mitra, Alla Sheffer, and Helmut Pottmann. Curved folding. *ACM Trans. Graph.*, 27(3):1–9, aug 2008.

[2] Mélina Skouras, Bernhard Thomaszewski, Peter Kaufmann, Akash Garg, Bernd Bickel, Eitan Grinspun, and Markus Gross. Designing inflatable structures. *ACM Trans. on Graphics*, 33(4), 2014.

[3] Yasaman Tahouni, Tiffany Cheng, Dylan Wood, Renate Sachse, Rebecca Thierer, Manfred Bischoff, and Achim Menges. Self-shaping curved folding: A 4d-printing method for fabrication of self-folding curved crease structures. In *Proceedings of the 5th Annual ACM Symposium on Computational Fabrication*, SCF '20, New York, NY, USA, 2020. Association for Computing Machinery.