Direct and inverse modelling of laser-cut meta-materials

Master-level internship, October 2018

Mélina Skouras, IMAGINE team, Inria Grenoble (France)
http://people.csail.mit.edu/skourasm/
melina.skouras@inria.fr

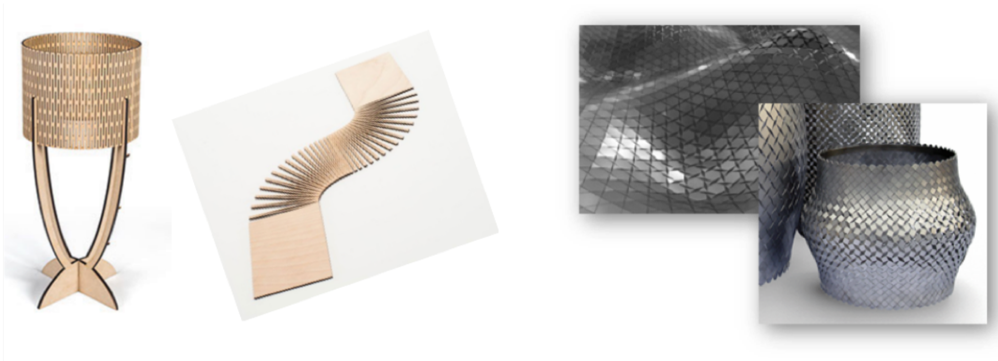

Figure 1: Changing the structure of plates of rigid materials such as wood or metal allows to increase their flexibility and therefore to broaden their mechanical properties.

Context

Meta-materials are materials whose mechanical properties arise from their internal structures rather than the properties of their constituent materials. By adding small cuts to a flat sheet of material, using for example a laser-cutter, we can easily fabricate 2D meta-materials, that can stretch significantly and take on doubly curved shapes when deformed. By varying the sizes and orientations of the cuts, the stretching behaviour as well as the appearance of the object can be modulated. This has interesting applications in industrial design, engineering, architecture and art. However, designing sheets with desired deformed shapes requires numerical tools that allow us to simulate and invert their deformation process. While previous work dealing with the computational fabrication of 3D objects from planar material focused on geometric aspects [2, 6], very little attention has been payed to the modelling of the physics of such structures.

Research goals

The goal of this project is to study the mechanics of laser-cut materials with a focus on non-linear effects (twisting, bending). To this end, we will leverage principles from homogenization theory [1] and its extension to non-linear materials [4]. We will also investigate how changing the cut patterns affect the macroscopic mechanical behaviour of the meta-materials and how we can spatially grade the microstructures on the sheets in order to obtain custom deformation effects while keeping the structures visually pleasing. Finally, we will integrate these algorithms into intuitive modelling tools that allow users to easily create free form structures out of planar sheets. Depending on the deformation capabilities of our engineered materials, we will consider one of the follwoing approaches: a physics-based direct modelling tool based on sensitivity analysis [3] to favour the exploration of the design space, or a fully inverse modelling system that directly takes as input a given target shape [5].

Requirements

The candidate should have strong programming and mathematical skills as well as knowledge in computer graphics, physics-based simulation and ideally computational fabrication.

References

[1] Grégoire Allaire. *Shape Optimization by the Homogenization Method.* Springer Science & Business Media, 2012.

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[3] Jesús Pérez, Miguel A. Otaduy, and Bernhard Thomaszewski. Computational design and automated fabrication of kirchhoff-plateau surfaces. *ACM Transactions on Graphics (Proceedings of ACM SIGGRAPH)*, 36(4), 2017.

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