GCM

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Student Project Proposal

As Isotropic As Possible Packing of Curved Beams

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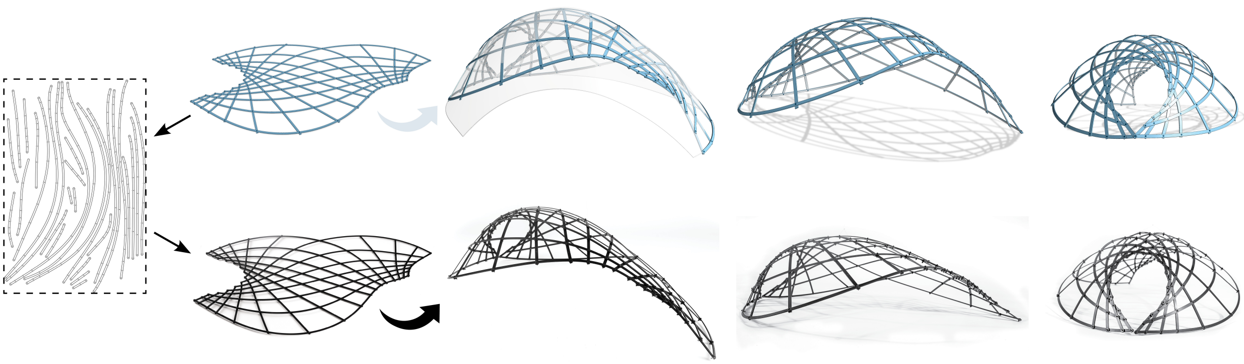

Figure 1: Once a satisfactory curved beams layout has been found (top row), the curves are extracted and manually laid out in a plane (left). The physical beams are laser cut from a sheet of material (here acrylic), and assembled at the joints using screws (bottom row). The simulated and fabricated models are shown in their flat (first from the left) and deployed states (three remaining renders). When the material is not isotropic e.g., plywood, orientation of the curves alters the beam's stiffness.

Description

Bending-active structures are composed of slender and/or planar elements that, upon actuation, bend and inject curvature to the structural form of the whole [1]. A particular instance of such structures are X-shells, which are compact and lightweight [2]. However X-shells often have residual stresses in their assembly (or undeployed) state. A recent extension ensures zero energy assembly state by allowing the beams that compose the linkage to have in-plane curvature in their rest state.

Such beams are fabricated by cutting large sheets of material following traced curves as shown in Figure 1. Larger scale models may require the use of anisotropic materials such as plywood, which spatially alters the curved beams stiffness. Aligning and splitting the curves so that they follow the direction of the plywood's fibers as much as possible is therefore desirable to comply to the simulated model. Fabrication constraints such as fitting the rods inside the laser cutter cutting area, and ensuring their non inter-penetrations need to be taken into account.

Although doable, manual positioning of the curves is tedious, and this project aims at automating the process by finding an optimal layout.

Milestones

The goals of the project may be summarized as

- Understanding the DER model, and getting used to the simulation codebase e.g., updating the material properties locally, deploying structures;

- Formulating the optimization problem. The curved rods are cut and oriented in the material plane so that the layout is as compact as possible, and the rods are as isotropic as possible, under non-penetration constraints;
- Implementing the objectives and constraints of the optimization problem;
- Fabricating the output C-shell.

Prerequisites

Good knowledge of at least one programming language is required, preferably Python or C++. Since setting up the cutting/packing optimization is core to the project, prior exposition to optimization is mandatory.

Remarks

The project is intended for Master students in the context of a 8 or 12 credits semester project.

References

[1] Julian Lienhard and Christoph Gengnagel. Recent developments in bending-active structures. In *Proceedings of IASS Annual Symposia*, volume 2018, pages 1–8. International Association for Shell and Spatial Structures (IASS), 2018.

[2] Julian Panetta, Mina Konaković-Luković, Florin Isvoranu, Etienne Bouleau, and Mark Pauly. X-shells: A new class of deployable beam structures. *ACM Transactions on Graphics (TOG)*, 38(4):1–15, 2019.