Optimizing support structures for freeform architecture

Master-level internship, could be extended to a PhD

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(a) Self-supporting (b) Inflatable (c) Elastic

Figure 1: *Freeform architecture relies on a variety of techniques to produce smooth surfaces. A common challenge is to define the position of discrete support structures (pillars, strings, rods).*

Context

Freeform architecture refers to the creation of buildings made of curved surface patches. Figure 1 illustrates several low-cost manufacturing techniques to produce such buildings, such as self-supporting surfaces made of bricks (a), inflatable surfaces (b) and elastic surfaces (c).

Designing such buildings is very challenging because architects need to anticipate the physical behavior of the construction materials to achieve the desired shape. For example, self-supporting surfaces must not collapse under their own weight, while inflatable and elastic surfaces must deform to a desired shape subject to external forces.

Research goals

Several methods have been recently proposed to help design and fabricate freeform surfaces [1,2,3]. In particular, interactive systems provide realtime simulation feedback to help users quickly evaluate different design alternatives, or optimize design parameters to best reproduce a target shape. However, most of these methods assume that the overall structure of the building is provided as input. For example, [1] requires the position of support points (pillars), [2] asks users to draw the seams between inflatable patches, while [3] asks users to draw elastic rods that will support the deformable surface.

Our goal in this internship is to automatically define the overall structure of such surfaces. We will focus on similar elastic surfaces defined by rods as in [3], although we hope that our approach could generalize to self-supporting and inflatable surfaces. The method would take as input a target 3D shape, and jointly optimize the structure of the elastic rod network and its parameters to best reproduce the shape in the physical world. The main challenge of this research is that the support structures correspond to discrete degrees of freedom (existence or absence of an elastic rod at a point), which result in a very large number of potential solutions. We plan to combine geometric heuristics, stochastic optimization and fast simulation to explore this solution space efficiently and find a good balance between surface quality and complexity of the support.

Work environment and requirement

The internship will take place at Inria Sophia Antipolis and will include an extended visit at Inria Grenoble. Inria will provide a monthly stipend of 1100 euros for EU citizen and 400 euros for non-EU.

Candidates should have strong programming and mathematical skills as well as knowledge in computer graphics, geometry processing and physical simulation.

This internship may be extended to a PhD.

References

[1] Designing Unreinforced Masonry Models
Daniele Panozzo, Philippe Block, Olga Sorkine-Hornung
http://igl.ethz.ch/projects/masonry/

[2] Designing Inflatable Structures
Melina Skouras, Bernhard Thomaszewski, Peter Kaufmann, Akash Garg, Bernd Bickel, Eitan Grinspun, Markus Gross
https://www.disneyresearch.com/project/designing-inflatable-structures/

[3] Computational Design and Automated Fabrication of Kirchhoff Plateau Surfaces
Jesus Perez, Miguel Otaduy, Bernhard Thomaszewski
http://www-labs.iro.umontreal.ca/~bernhard/Projects/KPS/KPS.html