Design of metamaterials

MSc internship proposal 2021-22

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Context

Recent advances in digital fabrication and material science raise various exciting new research challenges in computer science with applications to product design, architecture, medicine and art. One of them relies on the fact that 3D printing technologies, coming along with increasing computational capabilities, nowadays allow to realize more complex geometries and even to control the deformation behavior.
An example are metamaterials which gain their extraordinary effective properties from rationally designed geometric structures rather than their constituting material. Metamaterials enable to obtain new mechanical properties of standard materials by change of geometry. For example, a rigid wooden plate or an aluminium sheet can be made very flexible by cutting notches, see Figure 1.

Figure 1: Examples of metamaterials: their mechanical behavior is governed by their geometric structure and not by the material they are fabricated of.

Research Goal

In this internship we focus on a class of metamaterials, called auxetics. Auxetic material have the counter-intuitive deformation behavior: instead of becoming thinner when stretched, they become thicker. The top row in Figure 1 shows auxetic metamaterials.
The goal of this intern ship is to develop a geometric approach for a new type of auxetic structures, similar to [4]. In contrast to the examples shown in Fig. 1, which are composed of deformed 2D structures, we will focus on a volumetric structure. We will develop a geometric algorithm constructing structures with tailored mechanical behavior, such as auxeticity. Once the new structure is computed, we will use it as a micro-structure and investigate the question if it's possible to patch them together periodically in order to fill a 3D geometric object with tiles from it. The numerical simulation has to be adapted. Figure 2 illustrates the procedure for a very simple microstructure.

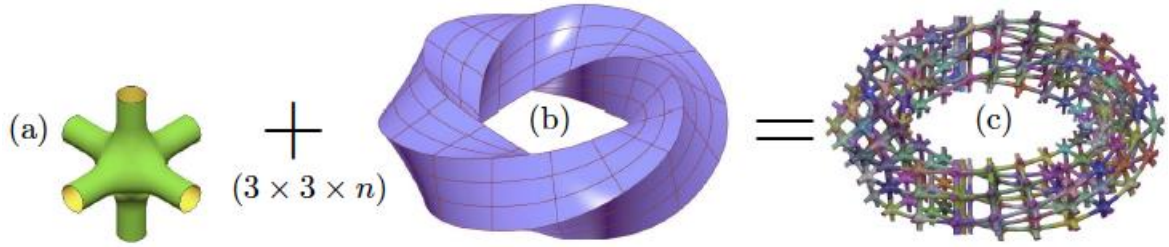

Figure 2: volumetric micro-structure with parametric tiles

Required skills

We are looking for a student with a combined math-informatics profile who is interested in geometric algorithms and data structures and graphical programming and who has good knowledge of linear algebra, numerical methods and who can easily program in C ++. Curiosity and enthusiasm are essential too.

Information for applicants and requirements

The internship will take place in the ANIMA team at INRIA Grenoble, 655 avenue de l'Europe, 38330 Montbonnot. The candidate should have good knowledge in geometric modeling and numerical algorithms and solid experience in computer graphics programming.
Please send your application (CV, University transcripts Bachelor and Master and motivation) to Stefanie Hahmann and Georges-Pierre Bonneau.
Feel free to contact Stefanie Hahmann for any further information about the internship.

References

[1] Auxetic mechanical metamaterials, H. Kolken, A. Zadpoor, RSC Advances, 7 (9), 5111-5129
[2] Fady Massarwi, Trivariate volumes - Algorithms and Applications, Ph.D. Thesis, Technion
[3] Star-shaped metrics for mechanical metamaterial design, Jonàs Martínez, Mélina Skouras, Christian Schumacher, Samuel Hornus, Sylvain Lefebvre, and Bernhard Thomaszewski. ACM Trans. Graph. 38(4), 2019.
[4] Geometric construction of auxetic metamaterials. Georges-Pierre Bonneau, Stefanie Hahmann, Johana Marku. (Eurographics 2021), Computer Graphics Forum 40 (2), pp.291-303 (2021).