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## GENERATION OF ANALYSIS SUITABLE B-SPLINE BEAM MODELS USING VIRTUAL IMAGE CORRELATION

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### ABSTRACT

The characterization of lattices or foams may require to build a geometric and mechanical model for each specific sample. A method to build an explicit analysis-suitable B-Spline beam model directly from digital images is presented. More precisely, we present an extension of the Virtual Image Correlation method to the case of multiple interconnected beams with variable cross-sections. The performance of the method is demonstrated through a series of examples involving synthetic and real images of lattice and more general cellular materials.

**Keywords:** image-based models, lattice structures, isogeometric analysis, virtual image correlation, cellular materials

### INTRODUCTION

Cellular material, namely foams or lattices, are characterized by complex architecture where the material is concentrated in small spans or thin webs, at an intermediate scale between the constituents and the structure. This particularity provides these materials with remarkable specific properties. The recent development of new manufacturing processes (especially additive manufacturing), pushes these materials to a new stage. Many open questions are stirring up the scientific community, in particular, multiscale modelling, characterization of the associated parameters, fast and accurate simulation, and geometric hazard.

In essence, foams have a random architecture, thus their geometry is locally variable and unknown. For lattices, defects inherent to additive manufacturing processes are known to introduce non-negligible geometric biases. In view of identifying the mechanical properties, the geometric characterization of the sample is therefore of paramount importance to build a digital mechanical twin associated to each individual tested sample.

There are mainly two classes of image-based models. First, immersed methods consist in building a structured embedding mesh not compatible with the topology of the object in the image. The technique then consists in defining an integration rule that is consistent with the topology to integrate the constitutive behavior only in the area where there is material. These methods do not require the knowledge of the topology of the sample *a priori*, which makes them versatile with respect to the geometric complexity of the sample.

In contrast, the second approach concerns template-fitting methods that build an explicit geometry usually based on splines (or finite elements) and are accompanied by a control point (or node) fitting procedure. These methods require starting from a description whose topology is compatible with the shape of the object but, in turn, they have the advantage of providing an explicit compact CAD description.

In this talk, we present an image-based modelling technique which principle lies in this second class of methods. In order to achieve the lightest possible model, and given the morphology of the materials considered, the method aims at building an explicit beam model based on B-Splines which is analysis-suitable in the sense that it is directly ready for beam simulations. To do so, we propose to extend the Virtual Image Correlation algorithm to the case of branching beams. We also aim at characterizing the potentially evolving cross-section thickness of each beam [4]. Note finally that we also propose an automatic initialization strategy in situation where the topology is unknown a priori, such as foams.

Technically, the sample is described as a set of interconnected quadratic B-Spline beams. Focusing here on 2D problems, two degrees of freedom (dof) are associated with each control point position. Additional degrees of freedom are introduced that describe the thickness of the beams. All these dofs are adjusted to minimize a distance between the real image and a synthetic virtual image computed as a function of the dofs.

## RESULTS AND CONCLUSIONS

Synthetic and real examples of increasing complexity are presented to illustrate the workflow from digital images to mechanical simulation. The results show that the proposed VIC variant is able to efficiently build an analysis-suitable interconnected beam model from graylevel images. In addition to the geometry of the center-line of the beams, the algorithm also provides an explicit description of the varying cross-section thickness. Particular care is also given to initialization. It appears in the studied numerical examples that considering the thickness in addition to the centreline position acts as a regularization which provide robustness.

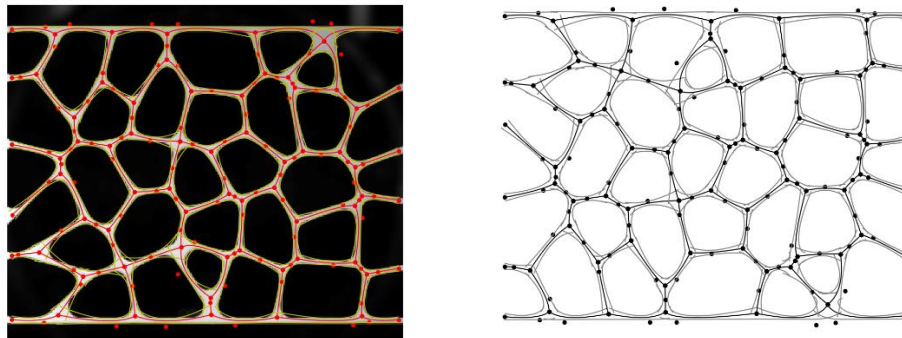


Fig. 1 – Construction of an analysis suitable B-Spline beam model from a digital image of a foam type sample

## REFERENCES

- [1] M. L. François, B. Semin, H. Auradou, Identification of the shape of curvilinear beams and fibers, in: *Applied Mechanics and materials*, Vol. 24, Trans Tech Publ, 2010, pp. 359–364.
- [2] Z. Jiang, J.-F. Witz, P. Lecomte-Grosbras, J. Dequidt, C. Duriez, M. Cosson, S. Cotin, M. Brieu, B-spline based multi-organ detection in magnetic resonance imaging, *Strain* 51 (3) (2015) 235–247.
- [3] A. Rouwane, R. Bouclier, J.-C. Passieux, J.-N. Périé, Architecture-Driven Digital Image Correlation Technique (ADDICT) for the measurement of sub-cellular kinematic fields in speckle-free cellular materials, *International Journal of Solids and Structures* 234-235 (2022)
- [4] O. Weeger, S.-K. Yeung, M. L. Dunn, Fully isogeometric modeling and analysis of nonlinear 3D beams with spatially varying geometric and material parameters, *Computer Methods in Applied Mechanics and Engineering* 342 (2018) 95–115.