

Elastic regularization of Digital Image Correlation: An application to cellular materials.

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Characterizing the mechanical behavior of materials with complex microstructures has become necessary in order to design low-priced and efficient structures. In the aerospace industry, for example, complex materials such as foams or honeycombs are widely used in sandwich panels due to their low density and high stiffness. But the need is not limited to industry. In biology, for instance, an accurate characterization of the mechanical behavior of bones could contribute to a better design of bone grafting components. In this context, Computed Micro-Tomography (μ -CT) has clearly become one of the most efficient non-invasive imaging tools for representing and inspecting the physical reality of such materials.

The present work aims at developing a procedure to identify mechanical properties of cellular materials (see Fig.1) using a rigorous dialogue between full field measurements and numerical simulations based on CT images. This kind of dialogue is practically inscribed in the Finite Element Method Updating (FEMU) class of algorithms [1]. On the one hand, it is necessary to simulate the mechanical response of the material (direct problem). Given the CT images, we can try to build a faithful Digital Image Based (DIB) model [2]. On the other hand, such an experimentation/simulation coupling requires minimally invasive measurements. Those measurements can nowadays be easily obtained using Digital Image Correlation (DIC, also named Image Registration in other fields of study) [3] or its three-dimensional variant called Digital Volume Correlation (DVC) [4, 5]. Unlike local matching techniques [6], the global DVC method facilitates this dialogue through finding a smooth unknown displacement field in a space of approximation suited for analysis. As a first step towards this long-term goal, our present contribution focuses only on the strain field assessment.

DVC in complex microstructures presents multiple changes and challenges when compared to 2D DIC. For instance, in most two-dimensional cases, a speckle pattern can be deposited onto the sample in order to introduce sufficient gray-level gradient values in the images. However, for DVC, the only information available is the intrinsic gray-level values of the material. That is why it seems that conventional DVC algorithms can only be applied when materials exhibit a natural speckle pattern (for instance graphite nodules [7]). In addition, the interpolation of the displacement field can be tricky. For example, when deforming cellular materials (see Fig.2 as illustration), localized deformations could occur. These deformations cannot be captured by low order shape functions used in traditional subset-based or finite element algorithms.

Our contribution concerns the development of a Free-form DIC algorithm that is capable of characterizing local deformations in cellular materials. For that we construct an automated DIB mechanical model and use it as a regularization for the DVC problem as proposed by Réthoré et al. [8]. When using voxel-based methods, which consist of converting the voxel data into a low order finite element mesh, a large number of degrees of freedom is obtained. Furthermore, when images are poorly resolved, non-smooth strain fields may be obtained due to the irregularities of the finite element mesh. In order to surpass the geometric problem, we use a B-spline level-set method in order to give a smooth description of the geometry represented by the voxel data [9]. Using this

level-set function, the mechanical solution is computed using non-conforming meshing techniques as proposed in [10].

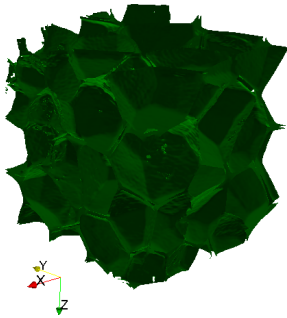


Figure 1. Three-dimensional reconstruction of a Polymethacrylimid closed foam.

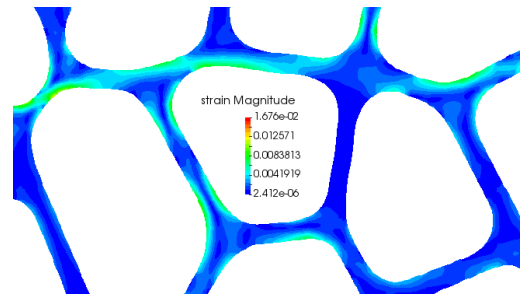


Figure 2. Local flexions are observed on the microscopic scale of a simplified two dimensional cellular material.

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