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Estimation of the strain field from full-field displacement noisy data : Can a filtering technique improve the identification of elastic properties ?

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ABSTRACT

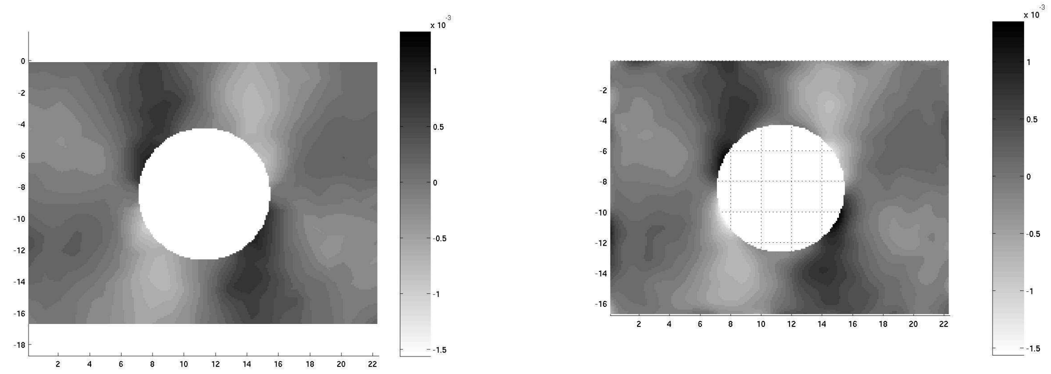
The recent development of digitized full-field displacement measurements opens new ways of characterizing materials in solid mechanics [1]. However, for most of the users of these techniques the strain fields rather than the displacement fields provide a real insight into the physics of the material at different scales. Therefore, except for the techniques which provide directly the displacement derivatives, it is necessary to differentiate the data. When the gradients of the displacement fields are relatively low, for example when the materials still behave elastically, the small measurement errors may induce large errors on the computed derivative [2]. So the key work is to develop a stable algorithm, in which it is possible to quantify explicitly the effects induced by noise differentiation.

A large number of algorithms can be found in the literature, [3]. One widely used way of performing this filtering consists in interpolating or approximating the data using smooth basis functions. The differentiation of the data is turned into the differentiation of the basis functions. For a given basis of functions, the regularization parameter is tied to the number of functions used in the basis. A good compromise between the faithfulness of the reconstruction (obtained with a large number of basis functions) and the efficiency of the low pass filtering (obtained with a small number of basis functions) has to be found.

However, a good choice of the basis functions is essential [4]. Previous studies [5] showed that a global polynomial basis leads to parasitic oscillations in the reconstruction when the degree of the polynomials is too large. Indeed, because of the global aspect of this type of bases, local artifacts in the data affect the whole reconstruction. Accordingly, it seems that basis functions that have limited interactions between each other would be more appropriate.

Two approaches fulfilling this requirement have been chosen in this study [6]. The first approach is based on global least-squares minimization using Finite-Element shape functions as the basis functions (FEA) [7]. The second approach is based on local weighted least-squares minimization using a polynomial diffuse approximation (DA) [8]. The regularization/precision parameter is the mesh size for the first approach, the span of the weighting function in the second one.

In a first part, we aim at comparing these two approaches and understand their behavior with respect to both noisy data and approximation errors. These comparison are performed on synthetic data obtained from the displacements of a Finite Element simulation who are added some noise. The reconstructed fields are illustrated on figure 1 for both methods.



(a) Finite Element Approximation

(b) Diffuse Approximation

Figure 1: ϵ_{XY} strain field reconstructed from noisy synthetic data

Then, the methods are applied to fields dedicated to the identification of elastic properties from heterogeneous tests. The identification is performed through the Virtual Field Method [9], that implies strain fields as input. The identification results are compared for various choices of filtering parameters and the improvement of the identification due to this filtering is adressed.

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