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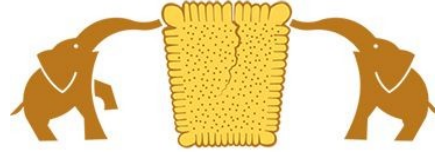
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Pixel-wise full-field strain measurements for analysis of strain heterogeneity

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Abstract — The pixel-wise method developed in "The secrets of the optical flow" is evaluated using +/-45°C carbon/epoxy specimen. The different regularization parameters are studied in order to evaluate the ones that can be used to enhance the estimation of the strain field.

Keywords — DIC, Optical Flow

Introduction

DIC algorithms currently used in mechanics often regularize the ill-posed optical flow problem by using a grid to reduce the dimensionality of the problem [2]. This grid can be local or FEM or even X-FEM [3]. It is quite common when we want to reduce the size of the elements to add a Tikhonov type regularization. The Optical Flow community also uses this type of regularization but chooses to use a grid at the pixel scale [1]. In order to preserve the discontinuities, they also use other types of norms such as Charbonier (quasi L1). In order to reduce the impact of noise, a modified median filter is used at each iteration on each component of the displacement field. This algorithm has been implemented in [4], but never used in mechanics to our knowledge.

The objective of this work is to analyze the impact of the regularization parameter, as well as to compare the Charbonier norm with the traditional least squares on the structure of the strains.

Methods

Two images of a tensile test on a plate with holes in a Carbon/Epoxy composite material were used in this respect, as this type of material has the particularity of creating a through discontinuity which provides an excellent test case to analyze the impact of the parameters of this algorithm on the discontinuity evaluated through the measured strains.

The eq. (1) is the optical flow using a given norm (ρ) :

$$E(u, v) = \sum_{i,j} \rho_D(I_1(i, j) - I_2(i + u_{ij}, j + v_{i,j})) + \lambda [\rho_S(u_{ij} - u_{i+1,j}) + \rho_S(u_{ij} - u_{i,j+1}) + \rho_S(v_{ij} - v_{i+1,j}) + \rho_S(v_{ij} - v_{i,j+1})] \quad (1)$$

with $\rho(x) = \sqrt{x^2 + \epsilon^2}$ for Charbonier or classical L² norm.

The eq. (1) is then derived and solved classically using a Gauss-Newton scheme.

At each step of the algorithm a median filter is applied in order to remove the outliers.

Results

The parameters that strongly influence the strain results are shown in Figure 1

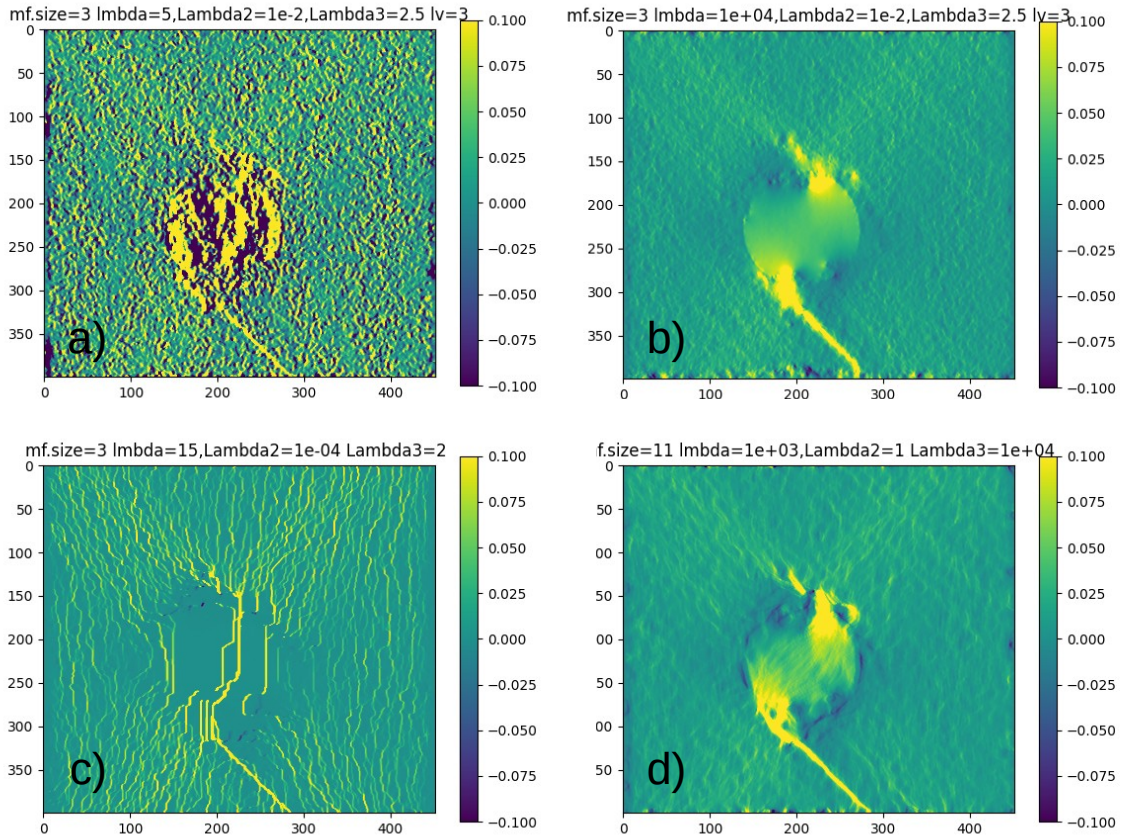


Figure 1: Von Mises strain for different parameter, a) L^2 with low regularization λ and low median, b) L^2 with higher regularization λ and low median, c) Charbonier with high lambda, d) L^2 with high λ and high median

Discussion and Conclusion

The results clearly show that the choice of the norm as well as the amplitude of the regularization parameter play a major role. While the Charbonier norm totally preserves the discontinuities, the quantization of the displacements imposed by this norm leads to spurious strains. The L^2 norm behaves in a completely predictable way by reducing the noise while diffusing the strains. The combination of the L^2 norm with a high value of the median filter gives less noisy results, but as the median filter is also an approximation of the L^1 norm, it allows to achieve a balanced result.

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