DETERMINATION OF STOCHASTIC FIELD OF YOUNG MODULUS FROM STRAIN MEASUREMENTS

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1. Introduction

This paper aims to present a method for computing the spatial distribution of stochastic material properties from known values of the strain field. Mechanical properties are usually defined by uniaxial compression and tension, bending, torsion or similar laboratory experiments. In all these cases, the material properties are calculated considering only global loading, measured strain, and, more recently, strain field through Digital Image Correlation (DIC) techniques. The determination of a specimen strain field is important to define mechanical-material properties throughout a non-homogeneous specimen, such as rocks and cellular structures. Neglecting the spatial variability of material properties can lead to inaccurate results when evaluating a solid behaviour and elastic properties, such as Young's modulus and Poisson ratio, which are conventionally assumed homogeneous throughout a sample. The proposed method attempted to compute the actual, spatial distribution of the material properties. The method was shown to converge to an accurate spatial distribution of Young modulus and Poisson ratio rapidly.

2. Digital Image Correlation (DIC) and the proposed algorithm

Digital Image Correlation (DIC) is an optical technique used to measure displacements and strains. The technique can be used to estimate the solid heterogeneity, from a set of measured strain observations in a selected domain. We have shown that an iterative approach to solving the systems of linear equations combined with the DIC measurements and a commercial finite element analysis (FEA) software such as Abaqus [1] can be used to compute the spatial distribution of the material properties within a sample. The approach developed herein leads to the determination of the field of mechanical-material properties – Young's modulus, E, and Poisson ratio, ν – based only on the spatial distribution of strains and the global loading and boundary conditions. The diagram below depicts the iterative process to determine the spatial distributions of E and ν.

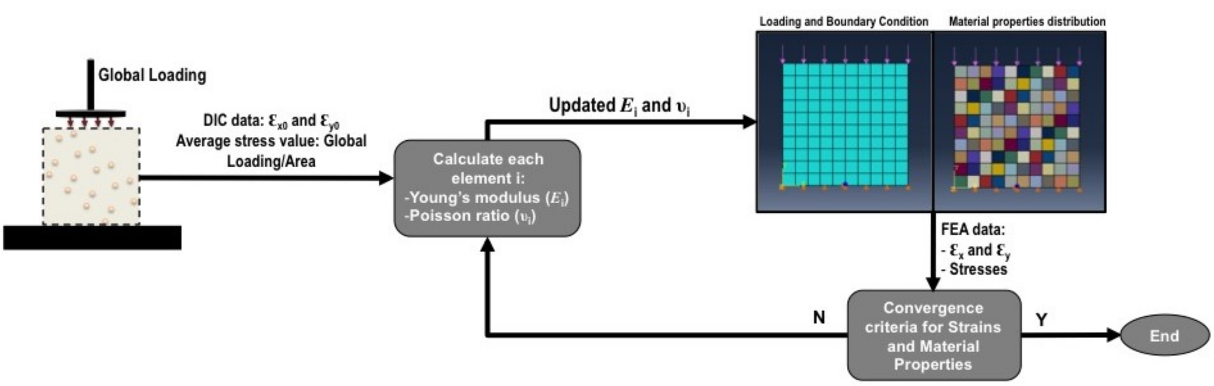

Figure 1: Iterative approach algorithm

In order to verify the proposed algorithm, a virtual experiment was considered. The virtual experiment was a plane stress problem, 10 by 10 elements (50 mm x 50 mm each). Each element had a different value of

Young’s modulus and Poisson ratio generated based on normal random distributions, with mean 29269 MPa and 0.203, respectively, and standard deviation of 10% of the mean values. E and ν were not correlated, and were independent variables. Strain field was used as an input into our proposed iterative algorithm to mimic DIC strain measurements of a thin plate loaded parallel to its plane by a uniform loading of 19.5 MPa. The measured strain field data and the information about the global loading, from the virtual experiment, were used to compute the spatial distribution of Young’s modulus using the proposed iterative approach. The convergence of Young Modulus and Poisson ratio using the proposed method is shown in Figure 2.

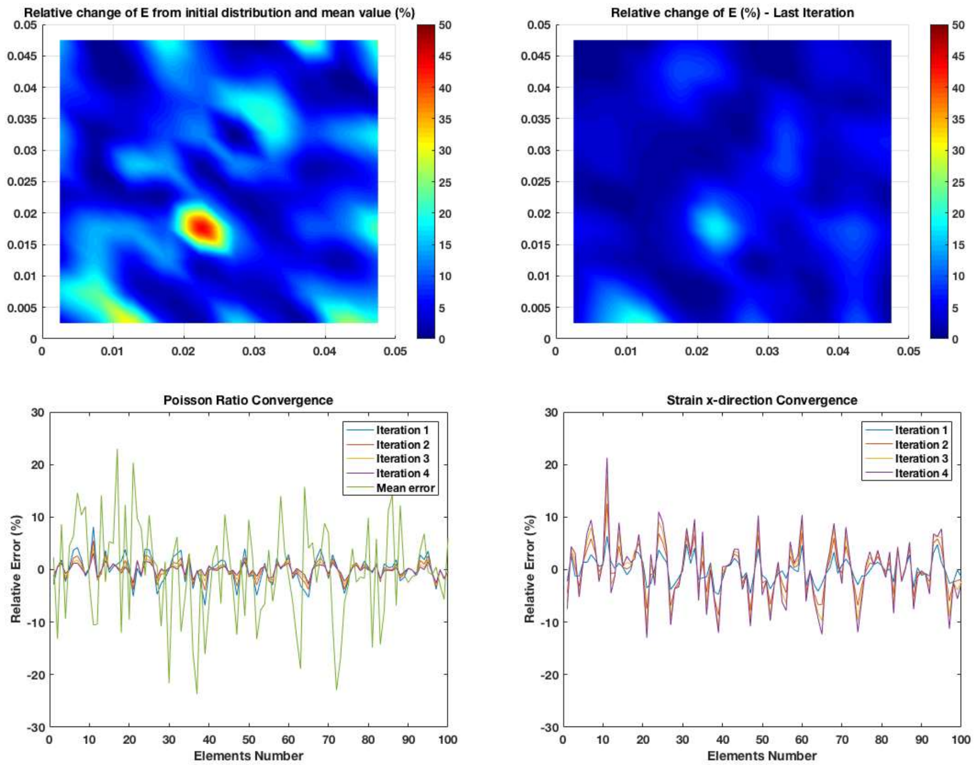

Figure 2: Relative change between iterations has been decreasing, hinging at the convergence of the algorithm as shown for Poisson ratio, axial strains. Colour maps show the convergence of the Young modulus.

5. Conclusion

The algorithm quickly converged to a spatial distribution of Young’s modulus. The computed values of Young’s modulus were within 1% accuracy when compared to the reference values in the FEA ‘virtual experiment’. Poisson ratio and strains also presented fair convergence. The results demonstrated the ability of the model to compute a spatial distribution of material properties from the given strain field and the global loading information only. Convergence criteria need further work such that one can determine if the given problem is going to converge and the solution can be found at the beginning of the computations.

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References

[1] Abaqus 2016 Student Edition.