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YOUNG'S MODULUS ESTIMATION AND LOAD IDENTIFICATION USING VISION AND FEM BASED PARTICLE FILTERING

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1 INTRODUCTION AND THE EXPERIMENTAL SETUP DESCRIPTION

This paper presents an example of a vision-based application of particle filtering (PF) [1] and finite element method (FEM) to two identification problems for a laboratory aluminum frame, shown in Fig. 1. In the first problem, we have successfully estimated the elastic modulus of the frame material. In the second problem, for known elastic constants, we have managed to identify the position and the magnitude of a quasi-static concentrated load.

In both problems, the solutions are based on the displacement field which is obtained with a digital camera, computer vision techniques and digital image correlation method (DIC), see Fig. 1. The main element of the system is the algorithm responsible for displacement measurements and material or load parameters estimation. The first phase of the algorithm is the full-field displacement measurement using PF for markers detection and DIC for markers tracking. The aluminum frame was loaded by application of a quasi-static concentrated force. This phase is described in more details in [2] and the results are shown in Fig. 2-A.

In the second stage, FEM and PF are used together to determine the Young's modulus E_{alum}. A single particle represents a particular value of E_{alum}. We have tested few FEM models with different number of FEs (see an example on the right-hand side of Fig. 2-C). The tests have shown that, in case of the loading force applied in the middle of the beam, it is enough to discretize the beam and the columns with only two FEs, respectively. The number of FEs should be increased when the force is applied in different points i.e. model nodes.

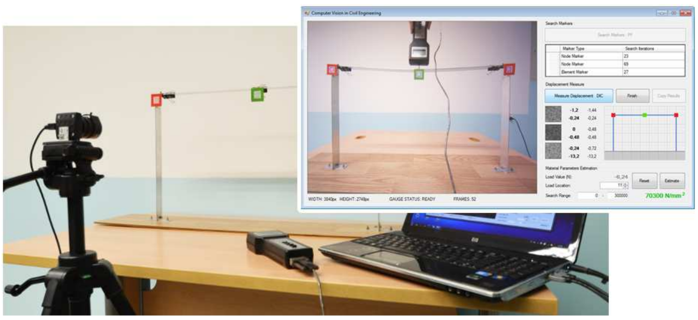

Figure 1: Test stand and the application interface.

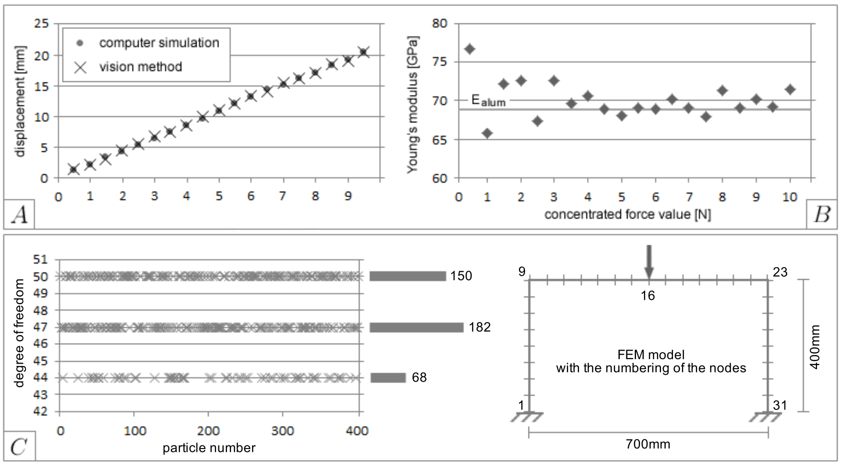

Figure 2: Plots of measured and computed displacement of the beam middle point (A), results for Young's modulus estimation (B) and results of load localization (C).

2 YOUNG'S MODULUS ESTIMATION

The first set of tests was carried out to estimate the Young's modulus of the elastic material. We have assumed that the actual value is $E_{\text{alum}} = 69$GPa. To fully test the PF approach, we have defined the initial range to be $0 - 500$GPa (no any prior knowledge). The estimation results are presented in Fig. 2-B. From the plot, it can be seen, that for small values of the force (less than $2N$), the mean relative error is about 6%. Increasing the force, the mean relative error amounts to 3% (less than $8N$). It is also important to note that the range size affects the number of iterations required to obtain the correct result.

3 LOAD IDENTIFICATION

The second set of tests was carried out to estimate the applied force magnitude, its localization and these two parameters simultaneously. During the tests, the load position was determined with accuracy of twice size of the finite element used in the FEM model. This means that in the last iteration when the stop condition of the algorithm is satisfied, all of the particles are assigned to the corresponding degrees of freedom of three adjacent nodes. The results for model with 30 FEs can be seen in Fig. 2-C where the force was applied in the middle of the beam and the 47th DoF corresponds to the element of the nodal forces vector in the vertical direction. During the tests, the load magnitude estimation mean relative error was about 5%. The tests were also carried out to determine the optimal number of particles in each case.

REFERENCES

[1] C. M. Bishop, *Pattern Recognition and Machine Learning*. Springer-Verlag, 2006.

[2] M. Tekieli, M. Słoński, *Computer Vision Based Method for Real Time Material and Structure Parameters Estimation Using Digital Image Correlation, Particle Filtering and Finite Element Method*. in Proc. of 12th Inter. Conf. on Artificial Intel. and Soft Computing (ICAISC-2013), Zakopane. [Accepted]