Automated Crack Detection and Measurement on large-scale Experiments based on Digital Image Correlation

Author(s):
Gehri, Nicola; Mata Falcón, Jaime; Kaufmann, Walter

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Automated Crack Detection and Measurement on large-scale Experiments based on Digital Image Correlation

N. Gehri, J. Mata-Falcón, W. Kaufmann

Institute of Structural Engineering, ETH Zurich, Switzerland

Abstract — The acquisition and evaluation of the crack behaviour in experiments on quasi-brittle materials, such as concrete, mortar, or masonry is essential for understanding their structural behaviour. This article presents a fully automated procedure to detect cracks and measure crack kinematics in experiments instrumented with digital image correlation (DIC). With appropriate parameters, the procedure allows detecting crack locations with high precision and measuring very accurately crack kinematics even for large-scale experiments with complex crack patterns.

Keywords — image processing, crack detection, crack kinematic measurement, automation

Introduction While knowledge on the design of conventionally reinforced concrete structures is well developed, there is a rising need and interest in the assessment of existing structures as well as in the use of non-conventional reinforcement, such as fibre or textile reinforcement and digital fabrication methods. A key aspect in understanding the structural response of such materials is the knowledge of crack mechanisms. For the validation and further development of sound structural mechanical models, surface crack measurements that allow several measurement stages are required in most cases.

Conventional crack measurement techniques, such as linear variable differential transformers (LVTDs) or optical tracking systems are limited to spatially discrete crack measurements. Using quasi-continuous (in time and space) DIC results of surface deformations allows detecting crack patterns and measuring crack kinematics. This article presents a procedure for the automated acquisition and evaluation of the crack behaviour using digital image correlation.

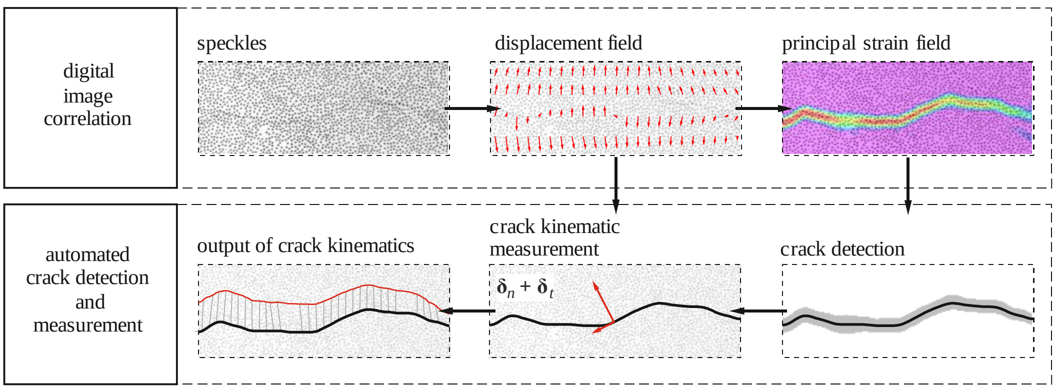

Figure 1: Flowchart of the automated crack detection and crack kinematic measurement procedure including the DIC pre-processing steps.

Methods The main concepts and steps of the automated crack detection and crack measurement procedure are detailed in [1] and summarised in Fig.(1). The specimen's surface is instrumented with a DIC system that tracks full-field displacements. Crack lines at the specimen's surface are extracted by means of classical image processing operations relying on the principal tensile strain field. Crack widths and slips are measured using a method for determining the local crack inclination and the calculation of the relative displacements of crack lips. The algorithm can be applied to individual measuring stages or to a complete measurement series of a test where the cracks are only detected once. The entire procedure runs fully automated in a MATLAB tool that allows controlling the processing parameters in a graphical user interface.

Results The performance and uncertainty of the proposed crack detection and measurement method have been assessed using test results from a small-scale panel experiment [1,2]. The results show that there is great potential for application to larger tests. The applicability of the crack measurement procedure to large-scale structural experiments is explored in the following.

Fig.(2) shows the crack measurement of the 2.00 x 2.00 m panel experiment PT-1 [3] loaded in pure shear in the Large Universal Shell Element Tester (LUSET) at ETH Zurich. The cracks are detected only once at ultimate shear load and used for the entire measuring series (i.e., some cracks have zero opening and slip in earlier load stages). Fig.(2a) shows the principal tensile strain field obtained from the DIC measurement at ultimate load. The results of the crack pattern and the crack kinematic measurement are shown in two automatically generated visualisations: (i) in Fig.(2b) with line widths proportional to the crack width at ultimate load; and (ii) in Fig.(2c) indicating the evolution of crack displacement vectors with crack lines shown in black.

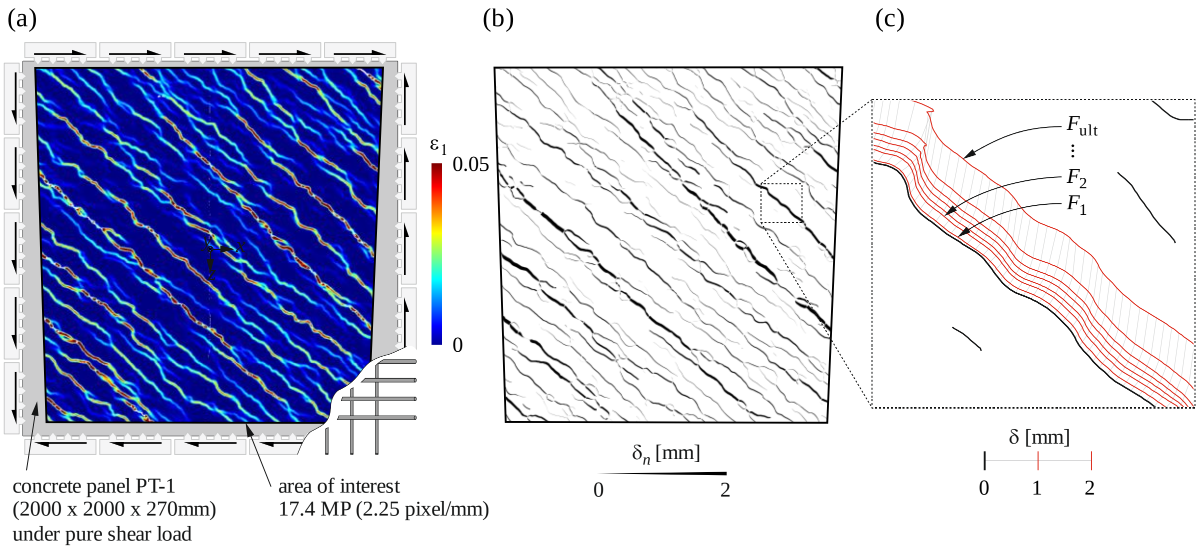

Figure 2: Crack measurement in the large-scale (2.00 x 2.00 m) panel experiment PT-1 [3]: (a) principal tensile strain field at ultimate load; (b) crack pattern with line widths according crack widths at ultimate load; (c) crack displacement vectors of successive measuring stages

Discussion and Conclusion While the proposed crack detection and measurement algorithm works perfectly for non-branching and well-separated cracks, the crack detection, and particularly the measured crack kinematics, might be biased for very closely spaced cracks and in areas near crack intersection. An automatic identification of reliable crack measurements should be addressed in future works, what would allow for statistical analyses without the risk of using biased measurements. The use of proper statistical evaluation tools will be essential for the consolidation of the very detailed data provided by the presented tool into more directly useable characteristic values of crack opening and slip.

References

[1] N. Gehri, J. Mata-Falcón, W. Kaufmann, Automated Crack Detection and Measurement based on Digital Image Correlation, Construction and Building Materials. submitted for publication (2020).

[2] J. Mata-Falcón, S. Haefliger, M. Lee, T. Galkovski, N. Gehri, Combined application of distributed fibre optical and digital image correlation measurements to structural concrete experiments, Engineering Structures. submitted for publication (2020).

[3] W. Kaufmann, A. Beck, D. Karagiannis, D. Werne, The Large Universal Shell Element Tester LUSET, Institute of Structural Engineering, ETH Zurich, Zurich, 2019.