OUT-OF-PLANE DEFORMATION MEASUREMENTS USING DIGITAL IMAGE CORRELATION

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Accurate measurement of 3D full-field deformation is paramount for the development of modern applications in structural engineering. Over the past decade, digital image correlation commonly referred to as DIC has emerged as a promising optical-based displacement measurement technique. Its usage in experimental science has gained popularity due to its advantages, including ease of use, high spatial resolution, non-contact nature, and reusability. While advanced DIC measurement systems exist, their high capital costs have limited their widespread adoption. Furthermore, most of the open-source DIC software systems are primarily designed for 2D measurements. Consequently, previous research efforts in DIC have predominantly focused on assessing materials with 2D deformations, with fewer studies addressing materials undergoing significant out-of-plane deformation.

This study introduces an innovative measuring tool based on DIC for the precise capture of 3D full-field out-of-plane deformation data. The proposed system utilises commercially available digital cameras and employs MATLAB-based algorithms for data processing and analysis. Uniaxial buckling tests were conducted on thin steel plate elements, considering their ability to induce significant out-of-plane deformations to validate the efficacy of this approach. A random speckle pattern was applied on the specimen surface to aid in feature detection and tracking. Simultaneous stereo images of the specimen were captured using two digital cameras at predefined loading intervals. Subsequently, the acquired images were subjected to disparity removal and rectification procedures.

From the generated disparity map, a 3D point cloud of the specimen was constructed, resulting in a 3D array of surface coordinates. Surface features of the specimen at each deformed stage were detected and extracted using the KAZE feature detection algorithm, leading to the generation of a 2D geometric transformation matrix for consecutive image pairs. By utilising this matrix in conjunction with the generated 3D point clouds, the displacement value of each pixel on the specimen's images was computed. Notably, an incremental correlation method was employed between successive images, as opposed to the conventional direct correlation method, to accurately capture significant out-of-plane deformations.

The displacement values obtained from the DIC system were subsequently validated against dial gauge readings. A comprehensive comparative analysis of the results demonstrates the capability of the proposed system to generate precise full-field displacement and strain maps in all three dimensions. The reliability and accuracy of the system in capturing substantial 3D deformations are underscored by the fact that the measurements obtained from the proposed system closely align, with a similarity exceeding 95%, further affirming its effectiveness.

Keywords: Digital Image Correlation, 3D point cloud, Out-of-plane deformations

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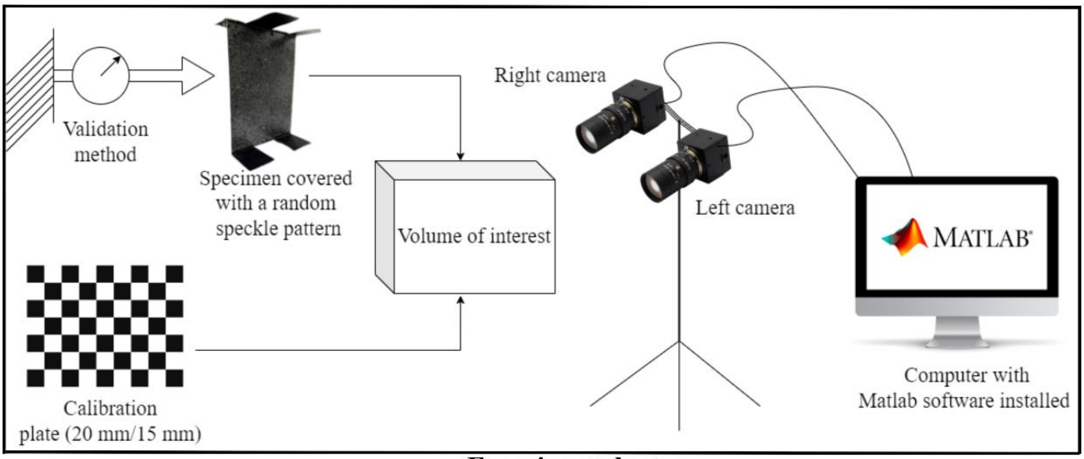

Experimental setup