Deformation Imaging to Assess Mechanical Stability in Hygroscopic Heritage Objects

Yun-Wen Liao[1], Adam Gibson[1 2], Josep Grau-Bove[1]

[1]UCL Institute for Sustainable Heritage
[2]UCL Department of Medical Physics & Biomedical Engineering

Abstract

An open-source, MATLAB-based Digital Image Correlation (DIC) software, Ncorr, has been applied for the first time to characterise the deformation response of two types of hygroscopic heritage materials following exposure to elevated humidity and subsequent desiccation. The preliminary results demonstrate DIC reliably captures the quantitative, full-field deformation of paper and canvas during the drying process: Humidified paper shows shrinkage upon drying, and the effect of the wood frame is evident on the mounted canvas. These findings confirm the methodological soundness of the approach, indicating its applicability for real-world preservation purposes, such as assessing the mechanical stability of hydroscopic materials subjected to environmental fluctuations.

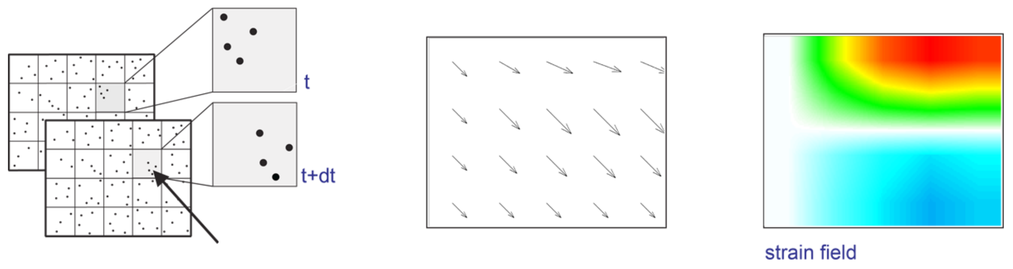
Introduction

Mechanical stability in heritage science is studied through a multidisciplinary approach that integrates materials science, engineering, conservation, and advanced diagnostics to assess and preserve the structural integrity of cultural assets. Key strategies and methodologies include:

- **Mechanical Characterization of Materials:** properties like stiffness, toughness, and modulus
- **Environmental Response Testing:** Simulate climate changes to assess material responses and damage thresholds
- **Numerical Modelling:** Use FEM and related methods to predict structural behaviour under stress.
- **Structural Assessment:** Integrate engineering and conservation data to guide stabilization choices.
- **Diagnostics & Monitoring:** Applies surveys and sensors to detect early signs of structural instability.

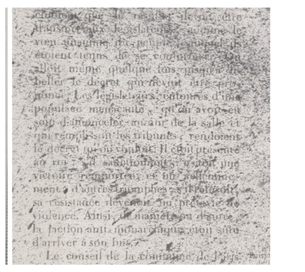
Methods

Digital Image Correlation (DIC) is a non-contact optical technique that tracks the movement of a speckle pattern applied to a material's surface. By comparing digital images taken before and during deformation, it calculates full-field displacement and strain with high accuracy.



Nikon D7500 DSLR camera for photography + MATLAB-based 2D-DIC Ncorr for DIC analysis

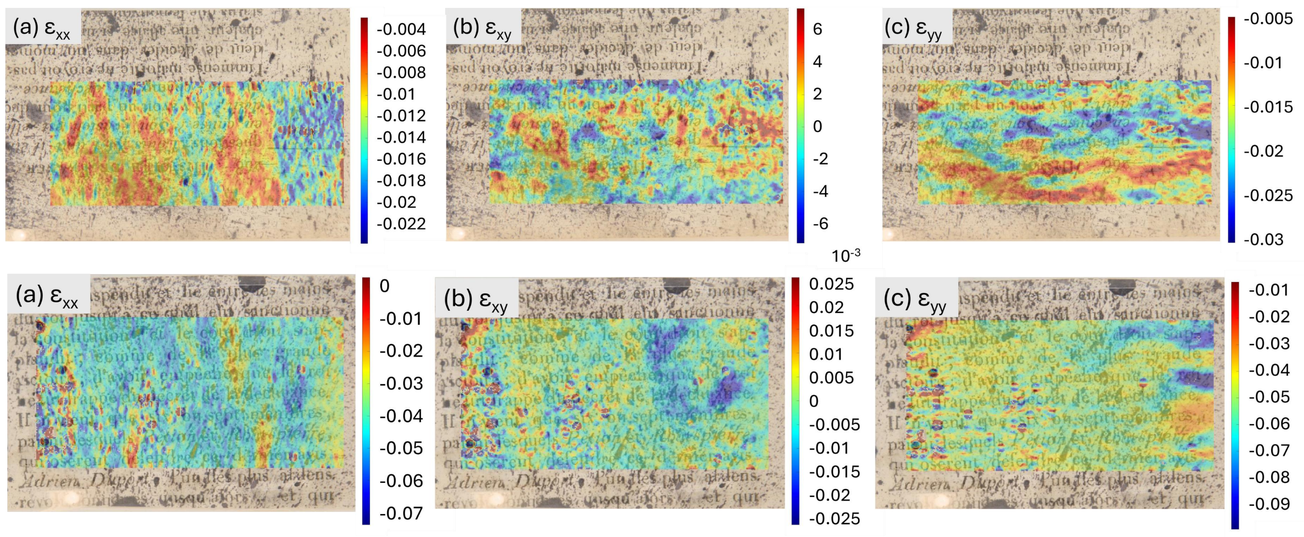
Results: Old rag paper



(A) Rag paper humidified in a container with hot water and exposed to vapour for 10 minutes

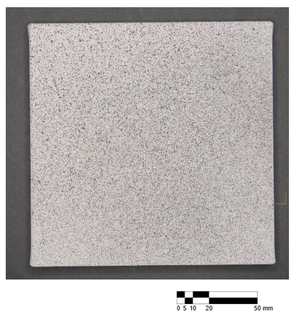
(B) Rag paper immersed in water to achieve an extremely high moisture content

Deformation (strain) profile after 20 min of drying:

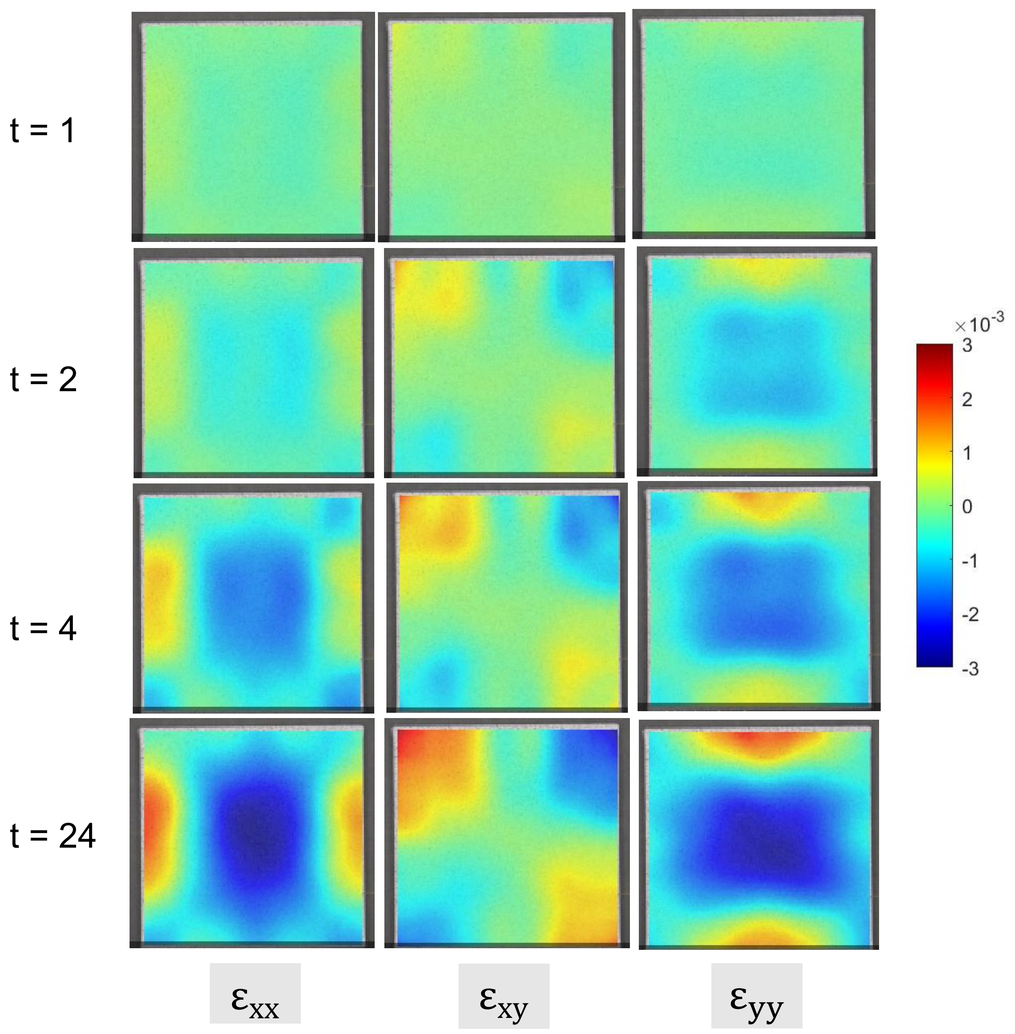


Results: Pre-stretched canvas

Canvas (15 × 15 cm): Humidified at 70 °C and 80% RH for 10 hours, then transferred to cold room conditions



Deformation (strain) profiles at 1, 2, 4, and 24 min after drying onset:



Discussion

These results not only confirm the methodological strength of digital image correlation (DIC) in capturing paper's response to environmental conditions but also demonstrate its potential for assessing the long-term mechanical impact of conservation treatments, some of which may inadvertently stress artefacts. By enabling evidence-based monitoring of deformation, DIC supports improved preservation strategies and informs environmental guidelines, thereby contributing to the sustainable care of cultural heritage.

References

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Yun-Wen Liao

yun-wen.liao.23@ucl.ac.uk