A Scalable Open-Source 2D Digital Image Correlation (DIC) Engine Capable of Handling Gigapixel Images

J. Hirst[1,a], L. Sibson[1,2], A. Tayeb[1], B. Poole[1], M. Sampson[1], W. Bielajewa[1], M. Atkinson[1], A. Marsh[1], R. Spencer[1], R. Hamill[1], L. Fletcher[1]

[1] United Kingdom Atomic Energy Authority, Culham Campus, OX14 3DB, Oxfordshire, United Kingdom
[2] School of Electrical and Electronic Engineering, University of Sheffield, Mappin Street, Sheffield, S1 4DT, United Kingdom

[a] Joel.Hirst@ukaea.uk

Abstract. Pyvale is an open-source software package being built for sensor simulation, uncertainty quantification, sensor placement optimization, and simulation/ calibration/validation. A key component of this is the development of a dedicated 2D DIC module intended for both standalone use and integration within broader experimental design workflows. Pyvale provides a user-friendly Python interface for DIC with performant compiled C/C++ routines underneath. At its core it is a multithreaded, reliability-guided DIC algorithm. Its open-source MIT license enables wide deployment, including on computing clusters and in automated pipelines. Benchmarking with the publicly available 2D DIC challenge 2.0 dataset shows that Pyvale achieves metrological performance comparable to established DIC codes. Pyvale's strong metrological foundation, coupled with the scalability needed for scanning electron microscope (SEM) DIC, positions it as a platform for sustained, community-driven DIC development.

Introduction

Digital Image Correlation (DIC) has become one of the most widely adopted non-contact measurement techniques for full-field displacement and strain analysis. Its flexibility, spatial resolution, and compatibility across optical and electron imaging systems have made it a cornerstone of modern experimental mechanics. Ongoing research has focused on improving its accuracy, computational efficiency, uncertainty quantification, and integration within broader experimental workflows [1,2].

Pyvale is an open-source software package that aims to provide an all-in-one framework for sensor simulation, sensor uncertainty quantification, sensor placement optimization, and simulation calibration/ validation. Central to this is support for image-based sensors, with a dedicated DIC module designed for both standalone use and integration within experimental design and sensor simulation workflows. The design philosophy behind the Pyvale DIC engine emphasizes a user-friendly Python interface coupled with high-performance compiled back-end code.

Implementation

The DIC engine in Pyvale uses a two-step approach: firstly, a multiwindow Fourier initialization procedure is used as an estimate for the rigid displacement of subsets. For SEM-DIC applications this can be well in excess of 1000 pixels. Once an estimate for the rigid displacement has been obtained, it then proceeds with a multithreaded Reliability Guided DIC (RG-DIC) [3] algorithm to calculate higher order shape function parameters.

Benchmarks of the DIC engine show comparative metrological performance when compared against anonymized DIC codes using open-source data from the 2D DIC Challenge 2.0 dataset [4]. We also examine the scaling of key quantities, such as runtime and memory usage, as a function of thread count and image size – which become important considerations for HRDIC, where images can be of gigapixel resolution

Case Study

A case study is presented that highlights Pyvale's capability to process gigapixel-scale scanning electron microscope (SEM) images in a single shot on a single workstation in minutes. An experimental reference and deformed image pair of oxygen-free high-conductivity copper was acquired using a 19×19 array of 20µm×20µm tiles at a resolution of 2048×2048 pixels per tile, resulting in an effective image size of approximately 32,000×32,000 pixels with displacements exceeding 1000 pixels. An example of the displacement and correlation maps outputted from a Pyvale calculation for an image of this size can be found in Fig. 1.

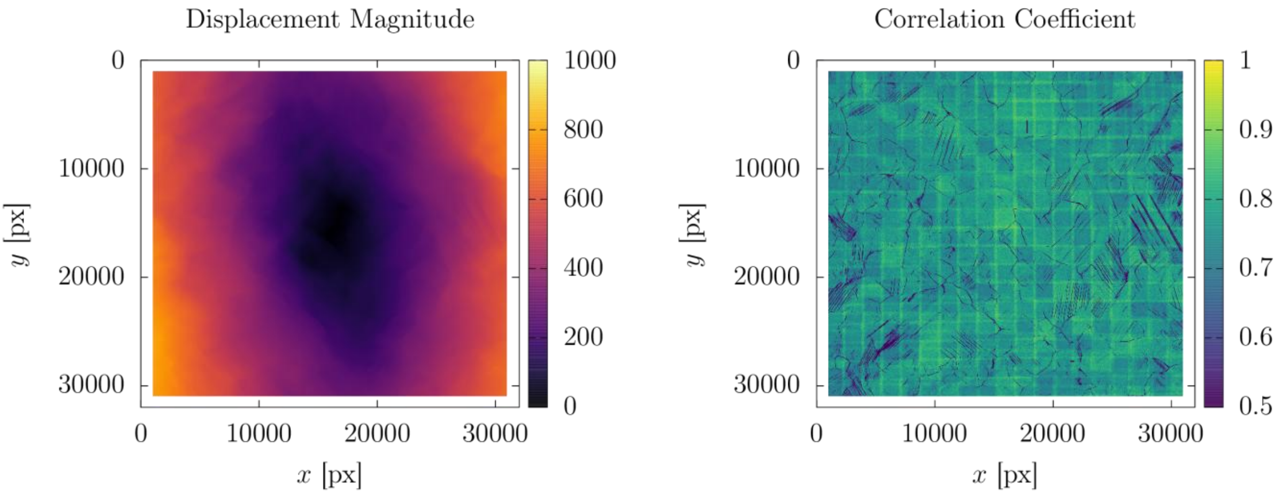

Fig 1: An example displacement (left) and correlation map (right) from SEM-DIC for a 32,000×32,000 pixel image with displacements approaching 1,000 pixels.

Conclusion

Finally, a roadmap for future development is outlined, including planned calibration and Stereo DIC modules, as well as strategies for user engagement and community contributions. As Pyvale matures, it aims to lower the barrier to entry for open-source DIC analysis while remaining extensible for advanced research applications. By combining a solid metrological foundation with a community-driven development model, Pyvale aims to become a platform for both standalone DIC use and integration within broader experimental workflows.

References

[1] Schreier H., Orteu J. J., Sutton M. A., *Image correlation for shape, motion and deformation measurements: Basic concepts, theory and applications*, Springer, New York, 2009.Pan B., *Digital image correlation for surface deformation measurement: Historical developments, recent advances and future goals*, Measurement Science and Technology, Vol. 29, No. 8, 2018.

[2] Pan, Bing. *Reliability-guided digital image correlation for image deformation measurement*. *Applied optics* 48.8 (2009): 1535-1542.

[3] Reu P. L., Blaysat B., Ando E., Bhattacharya K., Couture C., Couty V., Deb D., Fayad S. S., Iadicola M. A., Jaminion S., et al., *DIC Challenge 2.0: Developing images and guidelines for evaluating accuracy and resolution of 2D analyses: Focus on the metrological efficiency indicator*, Experimental Mechanics, Vol. 62, No. 4, pp. 639–654, 2022.