Multi-spectral data capture using reflective spheres for virtual experiments of Digital Image Correlation set-ups

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Abstract. Synthetic Digital Image Correlation (DIC) images can be generated using user-defined displacements and imaging system parameters. By comparing the displacements or strains as measured from the synthetic images against the virtually-applied displacements or strains, the uncertainty introduced by the measurement system can be quantified and the impact of different parameters investigated. However, current techniques for generating synthetic images do not include complex optical or thermal effects which are found in real set-ups, making the synthetic images unrepresentative of physical experiments. Taking inspiration from a technique used for visual effects in film and TV, it is shown that by imaging a sphere that is reflective in both near-infrared and visible wavelengths, a near-360° view of the test environment can be captured. It is demonstrated that by including measurements of test lighting and the thermal environment, synthetic images generated in the computer graphics software Blender can be made to closely match a real dataset captured in a laboratory environment. A fully-virtual design process for complex test set-ups is then possible, which takes into account the placement of lighting and hydraulic equipment which can impede measurement accuracy. Alternatively, the virtual twin of the test rig can be used to evaluate and subtract biases from the captured data for improved model validation and increased confidence in experimentally-derived results.

Possible Sessions

6. Data Driven Testing, 14. Model Validation, 19. Optical and DIC Techniques

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Measurement set-ups for full-field techniques, such as Digital Image Correlation (DIC) or Thermoelastic Stress Analysis (TSA) are applied to increasingly complex specimens and loading conditions and operated in increasingly challenging environments. They may involve multi-instrumentation, data fusion techniques, or large heterogeneous structures, for example in [1]. The test environment may be outdoors, subject to thermal shimmer from heat sources, or involve complex lighting conditions including changing daylight or self-shadowing from moving test components. These can introduce biases and increase random noise in the measurements and in the worst cases invalidate the whole test. Tools have therefore been developed for the modelling of the measurement set-ups in the virtual space, enabling the simulation of the measurement chain and the generation of synthetic datasets [2].

Several techniques for creating virtual reconstructions of DIC experiments have been demonstrated, including the use of the computer graphics software *Blender* for generating high-fidelity synthetic images, which can be used to predict the performance of a measurement system [3]. In these, ray-tracing algorithms simulate the physical behaviour of light in the measurement space to generate synthetic DIC images given input from finite element predicted deformation states, camera positioning, etc. The computer graphics approaches are based on those used to create visual effects ('CGI') for filmmaking, enabling complex optical effects to be accurately recreated for the generation of high-fidelity synthetic images.

A difficulty encountered in many full-field imaging set-ups is the presence of convection currents in the measurement space. These are caused by warm objects, such as hydraulic components surrounded by a colder laboratory environment. These constitute a significant source of uncertainty in a DIC measurements [4], which are virtually impossible to remove in post-processing. Whilst the ray-tracing algorithms used for some VEs are capable of simulating the behaviour of light passing through a turbulent refractive medium (i.e., thermal haze), current implementations of VEs for DIC do not model this behaviour. Additionally, existing demonstrations of virtual experiments for DIC have used simplified, user-defined test lighting. Test lighting can significantly impact DIC measurements, especially when the test set-up includes multi-camera measurements, complex lighting conditions or environmental lighting (e.g., sunlight). There is therefore a substantial risk that virtual predictions significantly differ from experimental measurements if the lighting is not accurately modelled.

A novel methodology was therefore developed that is able to simultaneously address the uncertainties caused by lighting and heat sources by capturing and recreating the environmental conditions in a multi-instrumented photomechanical measurement system. A reflective sphere is placed in the test rig in the place of a specimen and the DIC and TSA cameras (or a dedicated thermal camera) are used to capture the reflections in the sphere, as shown in Fig. 1(a) and 1(c). Since the sphere reflects light from all directions apart from the small region directly behind the sphere, the images can be transformed into a common coordinate frame [5] to provide the magnitude of the incident radiation as a function of direction, as shown in Fig. 1(b) and 1(d).

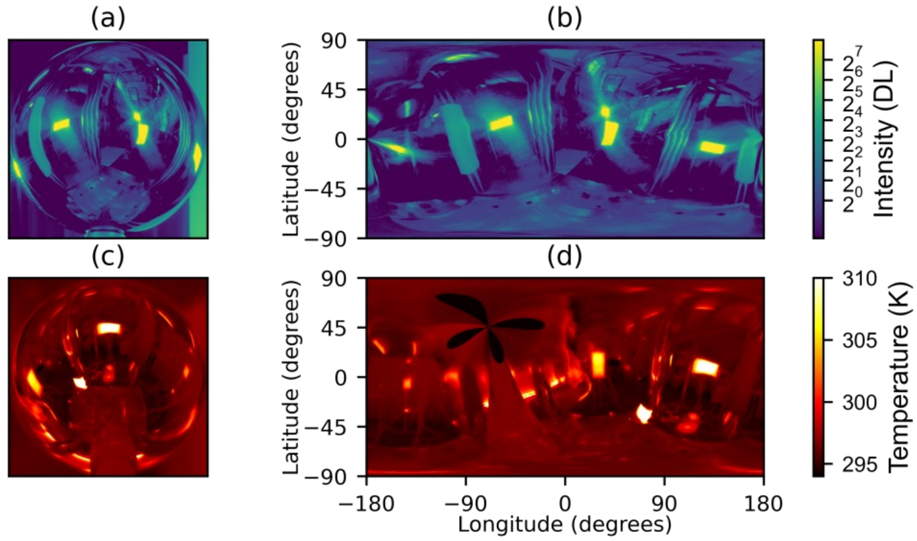

Fig. 1. Example use of mirrorball images. Visible light raw image (a) and its transformed version into a unified equirectangular coordinate system (b), and infrared raw image (c) and corresponding transformed image (d).

The measurements of the test lighting and thermal conditions can be used in a virtual experiment to improve the fidelity of the generated synthetic images. Fig. 2 demonstrates the procedure on an example specimen. The test lighting and thermal environment are reflected in the mirrorball and imaged using the DIC and thermal cameras. These images can undergo coordinate transformation to align them, and the information included in the virtual experiments. These virtual recreations then use the lighting information to generate synthetic images of a user-defined test object which are more accurate to the real experimental environment.

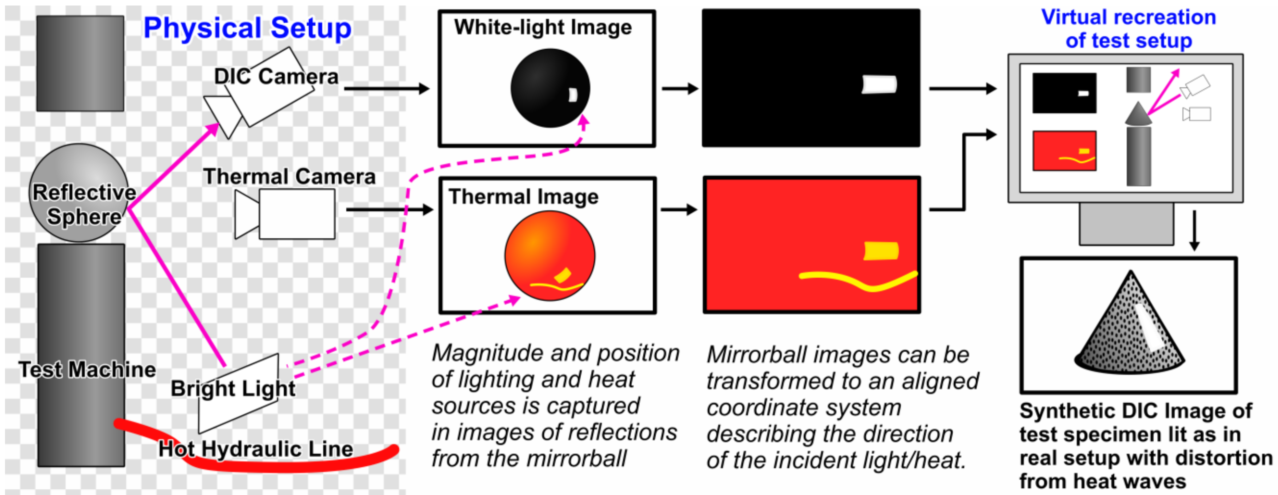

Fig. 2. Schematic diagram illustrating how virtual experiments can incorporate real-world lighting and thermal information to generate more accurate synthetic images.

The work demonstrates that an improved understanding of the real-world performance of complex photomechanical tests can be provided using the virtual testing approach. The novel technique for measuring the brightness and position of test lighting and the thermal environment in a unified coordinate system is shown to provide granular insight into the physical test environment. Hence, a detailed model of the measurement chain is developed that can aid model validation and the design of complex structural tests.

References

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