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Single-camera stereo-vision: on the use of robotics for digital image correlation

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ABSTRACT

Full-field measurement has proven to be extremely helpful in quantifying deformations on structures with complex shapes, loading history or with constitutive laws leading to localized phenomena. We presented in previous work (1) a strategy to design complex tests using the 3D modeling and rendering software *Blender* (2), for which we virtually set up a multi-camera experiment. This work showed that the virtual design of experiments can lead to huge gains in the design of their design as well as their actual installation. It covered not only the setup, taking into account the location of digital cameras as well as the possibility of obstruction and shadowing, but also proposed strategies for optimizing the experiments to be done by minimizing the (expected) measurement uncertainties thanks to the generation of synthetic images and the use of projection matrices.

Additionally, taking into account the numerical simulation (for example from a Finite Element code or software) can add more reliability into the results of the pre-design, into a framework we called *Virtual Testing*. In this framework, one can setup and make a virtual test for which the structure is deformed based on the numerical simulations. Synthetic images of deformed configurations can be generated to perform a virtual DIC measurement and ensure the feasibility of the real test. This led to the development of an add-on in *Blender* (3) (see Fig. 1).

However, even with this design stage, setting up complex experiments involving a high number of digital cameras (sometimes 10 or more), heterogeneous light sources, supports or cables may be really tedious and time-consuming and does not take into account changes that may occur during the experiment (local fracture, buckling modes, ...). We propose here an approach using a single digital camera mounted on a robotic arm to replace standard stereo systems and to offer a more versatile experimental set-up. A numerical 3D model of it can be used to find the appropriate locations of the camera, hence obtain a trajectory and command laws for the robot arm.

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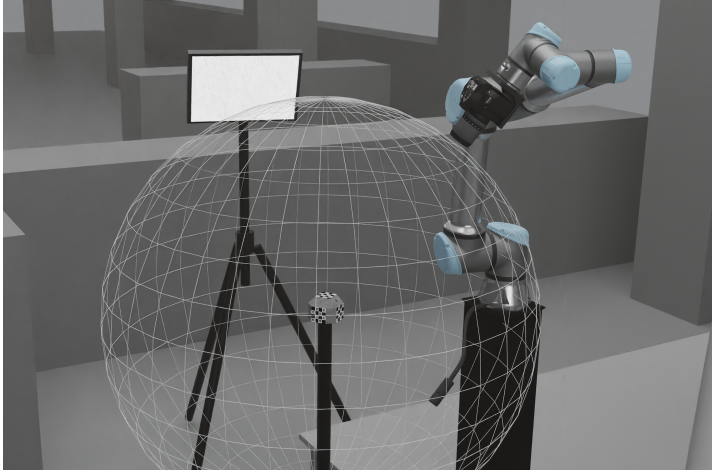


Figure 1. Virtual setup of a calibration test.

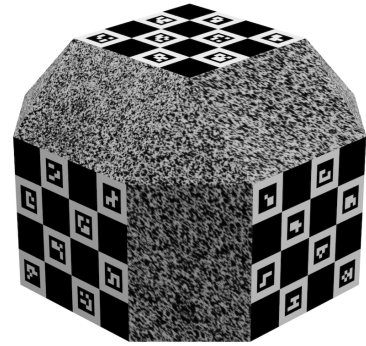


Figure 2. Calibration target with five ChArUco boards.

We also introduce a new strategy to calibrate the stereo camera system, by using a set of CharUco boards (4, 5) on a calibration target with a beveled cube geometry (see Fig. 2). The hybrid setup allows for a robust and quick estimation of the extrinsic and intrinsic camera parameters very efficiently using the CharUco board system (the real time estimation enables us to drive the robot according to the prescribed loading path or adjust it on the fly). Alternatively, the feature points of calibration target (*e.g.* edges and corners), can be easily selected, where the Perspective-n-Points algorithm (6) can be carried out. Moreover, the obtained camera pose from pre-calibration can be used as initial guess in the global S-DIC calibration (7) if an extreme accuracy of calibration is desired

The presentation will discuss several tests (both synthetic and real experimental acquisitions), performed on a sample designed such that its 3D buckled geometry has an analytical solution. For validation purposes, having a benchmark test to the S-DIC algorithm is extremely valuable. Validations of both the stereo calibration, and stereo displacement calculation are equally important. A specimen exhibiting a 3D complex closed-form solution is interesting in this regard.

The obtained results pave the way towards flexible and reactive data acquisition during mechanical testing, optimized at each instant of time and where the preparation stage of virtual testing has allowed to anticipate and clear possible difficulties.

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