Correction Fields, a new approach to Improve Calibration of DIC systems

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Abstract. The imaging of camera-based measurement systems is often described using simple physical models. The remaining deviations between the modelled and the real image can lead to increased errors, especially in the strain calculation for Digital Image Correlation measurements. With the approach of an additional correction field, which is calculated during calibration, the physical model can be extended and thus the strain calculation can be significantly improved.

Introduction

A common concept of calibration of Digital Image Correlation systems is based on a physical model of the imaging. Here a pinhole camera model is used with at least the focal length f and the position of the principal point PP in the image plane. In order to cover the distortion of the lens, deviations from the ideal projection are described by typically 4 or more rotational and tangential distortion parameters. In total about 8 to 10 parameters are used for each camera describing the projection of the object into the image plane. Theses parameter are the intrinsic parameter [1]. The extrinsic parameter describing the position of the camera relative to world coordinate system by a translation and rotation along all three axes X, Y and Z. The parameters are determined by use of bundle adjustment methods [2, 3]. However, the amount of distortion – e.g. due to imperfect lenses – this approach can model are limited. The remaining imperfections become more visible for larger movements of the object through the image and at lower strain levels. Therefore, a rigid body movement is an appropriated scenario for judgment of the calibration quality. The measured strain values should be zero for a pure movement of the object with no deformation. Insufficiently corrected distortions will lead to non-zero strain values and so define the smallest measurable strain values [4].

Determination of the Correction Field

In the new approach we combine the standard pinhole model with an additional non-parametric correction field, which covers the remaining and uncorrected distortion of the imaging. In the following step, the coordinate in the world coordinate system is now determined for each position of the calibration plate for each calibration feature. With the help of the previously determined pinhole parameters, the position of the feature in the camera image is determined. The deviations from the position detected in the camera image correspond to the remaining distortion of the image. With a sufficiently large number of feature points and calibration images, a corresponding number of correction values can then be determined in the camera image. Important is, that the position of the feature from the calibration plate, are known with a high precision and the calibration plate is sufficiently translated, rotated and tilted within the calibrated volume. For the correction field, an equidistant grid is created in the camera image – typically every 50-200 pixels – and depends, among other things, on the number and density of the determined correction values. For each grid point, an average value is then calculated from all neighbouring correction values and the complete correction field is determined from this. It should be noted that the correction values may also depend on the depth Z and is therefore calculated on at least 2 Z planes.

Improvements of using a Correction Field

For comparison we use a standard pinhole calibration model with 4 distortion parameters, an extended pinhole model using higher distortion orders with 14 parameters and the combination of the standard pinhole model with the correction field. We perform a rigid body motion test on a plate with synthetic speckle pattern. For different amount of shifts we use the three calibration models and calculate the strain on the sample. Since the object is not deformed, the strain should be zero on the total object. Deviations from zero will describe the quality of the calibration model used. For small displacements <1 to 5% FOV, the main random error source is the intensity noise of the images. For larger displacements the error is dominated by the imperfection of the calibration model yielding systematically bias. A rigid translation of a non-deforming object can so be used to quantify the quality of the calibration method used.

Verification

For the verification a plate with a synthetic speckle pattern of about 140x100 mm^2 at a working distance of about 440 mm is used. The DIC system consist of two 5MPx cameras, at a stereo angle of about 38°, each equipped with 25 mm lens.

A typical result for the x- and y-component of the correction field for one camera is shown in Fig. 1. Here, the correction field for each pixel is determined from the values of the grid points by bi-spline interpolation. The amplitude of deviation is in the range of below 1/20 of a pixel. The amplitude of the correction field is large enough to have a significant influence on the strain calculation. The shape of the correction shows that it cannot be modelled by a simple e.g. low-order polynomial model and thus is best captured with a non-parametric correction field on a sufficiently small grid.

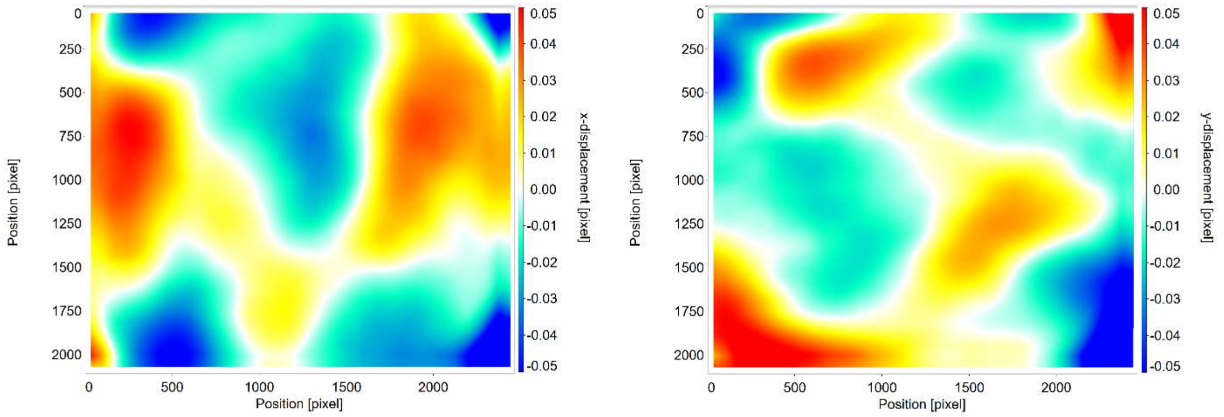

Figure 1: Correction field for X- (left) and Y-displacement (right) of camera 1 in pixels with 64 pixel grid size for the correction field

For the evaluation, 31 pixel subset size and 30 pixel step size are used. The following Fig. 2 shows the calculated strain from a rigid body translation of about 20 mm of the test object. The left side shows the comparable von Moisses strain using the standard pinhole model. The right side shows the result with an applied correction field. The strain noise can be reduced significantly with the use of the correction field.

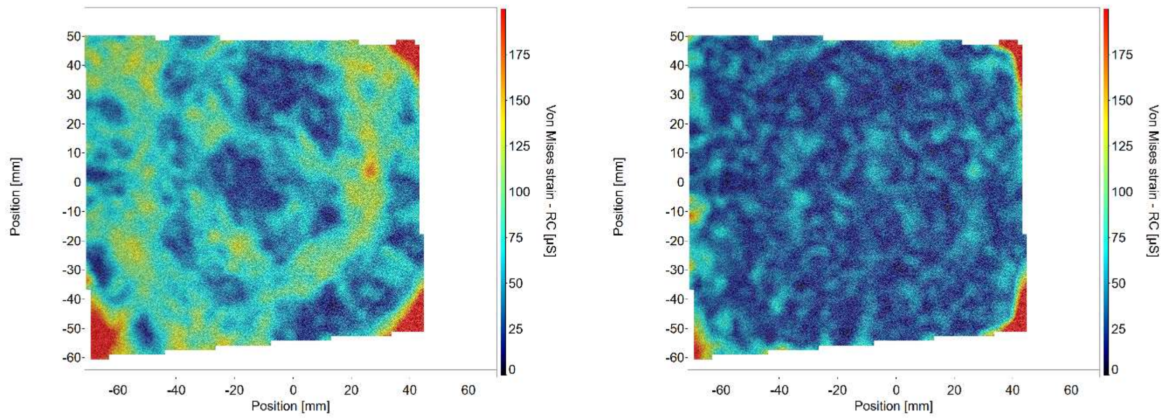

Figure 2: Comparable von Misses strain ε_{vM} of a rigid body translated object, without (left) and with (right) correction field

Conclusion

The method is validated for different lenses, working distances and apertures typically showing distortion values of up to 0.1 pixel, highlighting the need for such a correction field especially when the object is moving more than e.g. 10% across the field-of-view and in need of measuring accurately small strain values.

References

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