Investigation of influence factors of photomechanical measurement errors

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Abstract: Owing to the different advantages such as full-field and non-contact measurement, photomechanical methods are widely used in experimental mechanics. However, there are many factors affecting the measurement error due to the complexity during experimental data acquisition and related post-processing. Currently, many researches are devoted to investigation of influences of image processing algorithms on the measurement error. However, the related laws are not enough to accurately describe the influence laws of factors that affect the measurement error. This paper investigated various factors in different steps of the photomechanical measurements, including surface preparation quality of the target, acquisition, storage and post-processing. The influences laws of these factors on the measurement error were systematically investigated. Finally, the photomechanical measurement error can be minimised through optimising the configurations in different steps of experimental tests.

Introduction

Photomechanical method is an experimental method to measure and measuring the mechanical parameters (e.g., motion and deformation) of the structure using mechanics analysis method based on the optical principle, which is an important branch of experimental mechanics [1]. Photomechanical methods have been widely used in scientific research and engineering applications, e.g., exploration, construction and transportation [2]. The accuracy is one of the most critical issue for related photomechanical measurements. However, for the photometry, experimental data acquisition and post-analysis are very complex. The main steps for photomechanical measurement are illustrated in Fig. 1. The surface preparation quality of the target, camera and lens configuration during image acquisition, the format and compression ratio during the image storage and the selection of image analysis algorithms largely influence on the final measurement error. Currently, many researches are devoted to minimising the measurement error by improving the surface preparation quality and developing different image processing algorithms [3, 4], but ignoring the influence factors during image acquisition and storage steps. In fact, the configurations for image acquisition and storage directly affect the image quality, which fundamentally influences the photomechanical measurement errors. Therefore, the present work systematically investigates the factors influencing measurement error during image acquisition and storage steps. The influence laws observed in the present work provide reference on optimised configurations for photomechanical measurements.

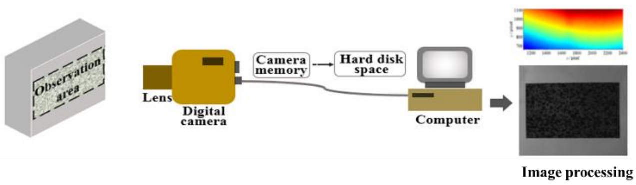
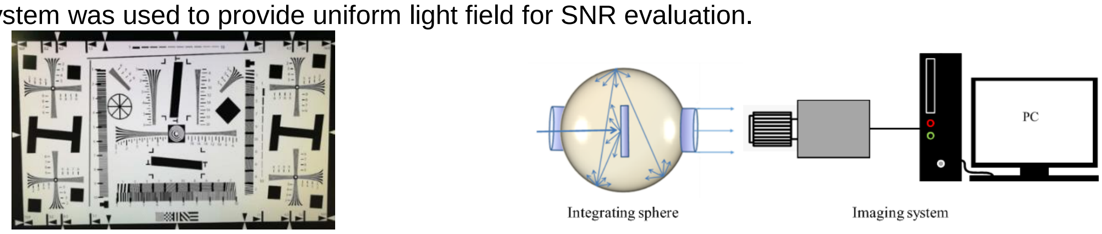


Fig.1 Main procedures for photomechanical measurement.

Experimental methods and systems

Image acquisition influences the measurement error through affecting the image quality. Therefore, the influence of different imaging modes (e.g., chromatic or monochromatic imaging, normal or high-speed imaging) and imaging configurations (e.g., camera and lens configurations) on the image quality should be considered. The image quality is usually characterised by spatial resolution and signal-to-noise ratio (SNR) [5,6]. In this work, the spatial resolution was semi-quantitatively evaluated using a test chart, as shown in Fig. 2a, which was also quantitatively evaluated using the modulation transfer function (MTF) under different configurations [5]. To evaluate the SNR of images, a system illustrated in Fig. 2b was employed. The integrating sphere in this system was used to provide uniform light field for SNR evaluation.



(a) (b)

Fig. 2 Evaluation of image quality. (a) Test chart, (b) Testing system for SNR evaluation.

Results analysis

The above system was used to evaluate the image quality under different configurations. For instance, the influences of monochromatic and Bayer chromatic imaging on the measurement error were investigated. Fig.3a and 3b shows the spatial resolution evaluation for a monochromatic and Bayer chromatic cameras with the same version under the same configurations (exposure time, gain, lens version and f-number). The quantitative spatial resolution evaluation for these two cameras is shown in Fig. 3c. It is clearly observed that the spatial resolution of the monochromatic camera is higher than that of the chromatic one. The SNRs of images were evaluated. The results show that the SNR of the monochromatic images is obviously higher than that of the chromatic image under the same imaging configurations, as shown in Fig. 3d.

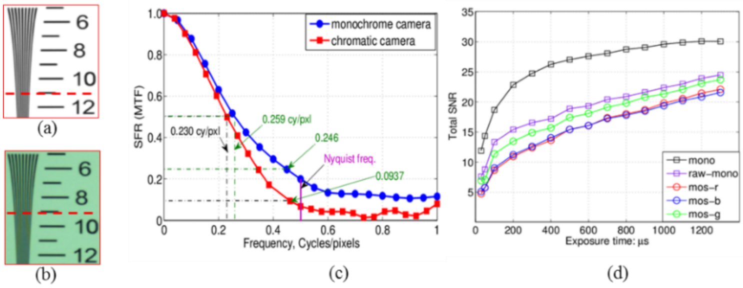


Fig. 3 Evaluation results for monochromatic and chromatic images. (a)/(b) spatial resolution of monochromatic/chromatic images, (c) /(d) MTF/SNR of monochromatic and chromatic images.

In addition, taking the DIC method as an example, the influence of chromatic imaging and monochromatic imaging on the measurement error under the same imaging settings was investigated. The systematic and random error of uniform deformation measured by monochromatic and chromatic imaging are shown in Fig.4. The results show that the chromatic measurement error is significantly higher than the same type of monochromatic camera.

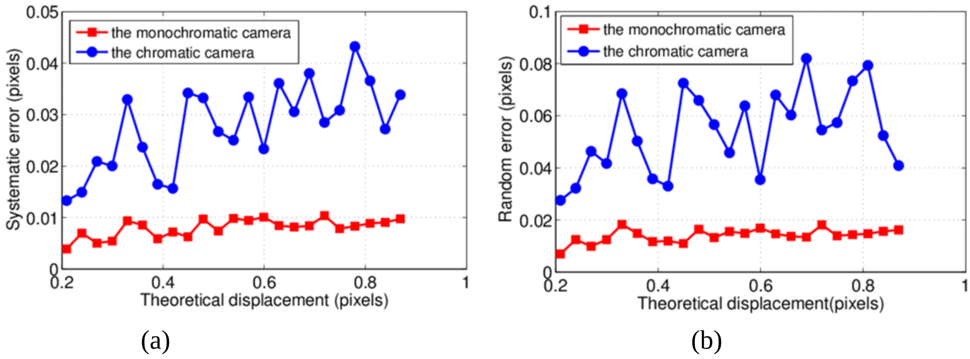


Fig. 4 Measurement errors with monochromatic and chromatic images. (a)/ (b) Systematic/random errors.

Conclusion

Based on investigation in the present work, it can be concluded that the configurations during each steps of the photomechanical measurements affect the error, and the influence factors in each steps on the measurement error are different. It is found that the improvement on SNR of images through lengthening the exposure time and increasing the effective aperture are similar. The performance of prime lenses is better than that of zoom lenses. The photomechanical measurement error using chromatic camera is greatly higher than the monochromatic counterpart. More details will be presented on the conference.

References

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