# Evaluating the Influence of Camera and Projector Lens Distortion in 3D Reconstruction Quality for Fringe Projection Profilometry

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**Abstract:** We study the influence of geometric distortions of the camera and projector lenses on 3D reconstruction quality for fringe projection profilometry. Experimental results on real objects and their 3D models show the accuracy is improved.

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## 1. Introduction

The calibration of a Fringe projection profilometry (FPP) system is a crucial step for achieving accurate measurements. Despite the fact that many calibration methods have been proposed in the past [1], most methods ignore the influence of the geometric distortions of the camera and projector lenses on the reconstruction quality. Moreover, even when the distortions are taken into account the usual error analysis is based on reprojection error. A minimum reprojection error in the calibration images does not ensure the best reconstruction accuracy of arbitrary objects. Some authors have found that additional minimization of calibration parameters overfits calibration data and produces less accurate 3D models [2]. In this paper we evaluate the influence of the geometric distortions of the camera and projector lenses on 3D reconstruction quality for a FPP system. Our system is based on a camera-projector stereo vision system, in which the projector is regarded as an inverse camera [3, 4].

## 2. Experiments and results

The stereo camera-projector system works by searching for homologous image points in the camera and projector. The 3D coordinates of measured points can be reconstructed once system parameters have been determined. To detect system parameters and for searching corresponding points, horizontal and vertical fringes are projected onto a calibration plane placed in different positions and orientations. This plane is a checkerboard target with two colors, which are selected so that with gray-level projection the monochromatic camera response to the two colors are similar, but when the target is illuminated with red light, only the checkerboard image is detected in the camera. The calibration involves estimating the radial and tangential distortion coefficients for both the camera and projector. In our setup, the intrinsic parameters of both devices are estimated independently. Moreover, the geometric lens distortion compensation is carried out in camera and projector image coordinates to maintain accuracy.

We carried out several experiments for assessing the influence of lens distortion in 3D reconstruction quality. First, we reconstructed a 250x250 mm flat glass surface under different orientations and we computed the RMS error from the reconstruction to the ideal 3D model of that of a plane. In Fig. 1(a) we show the reconstruction error surface without lens distortion compensation for a given plane under orientation number 1 in Fig. 1(d). Note that the error decreases when the camera lens distortion is compensated, Fig. 1(b), but it decreases to a greater extent after both the projector and camera lens distortions are compensated (Fig. 1(c)) yielding an RMS error of 0.1215 mm.

Second, we studied the influence of lens distortion on the 360° reconstruction of objects. In our experiments we scanned a dented pipe for analysis. In Fig. 2 we show the dented pipe along with the two 360° reconstructions from partial 3D scans compensating the camera and projector lens distortions and without compensation. By looking at the profile in Fig. 2(d) we notice a significant difference in the shape and measurements of the pipe. A 1 mm difference in diameter is shown in the zoomed region.

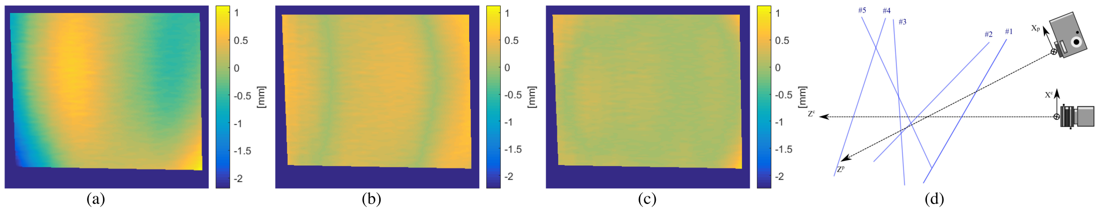

Fig. 1. Reconstruction error for a flat surface. (a) Without lens distortion compensation (RMS error 0.4501 mm), (b) with camera compensation (RMS error 0.3173 mm), (c) with camera and projector compensation (RMS error 0.1215 mm), and (d) setup.

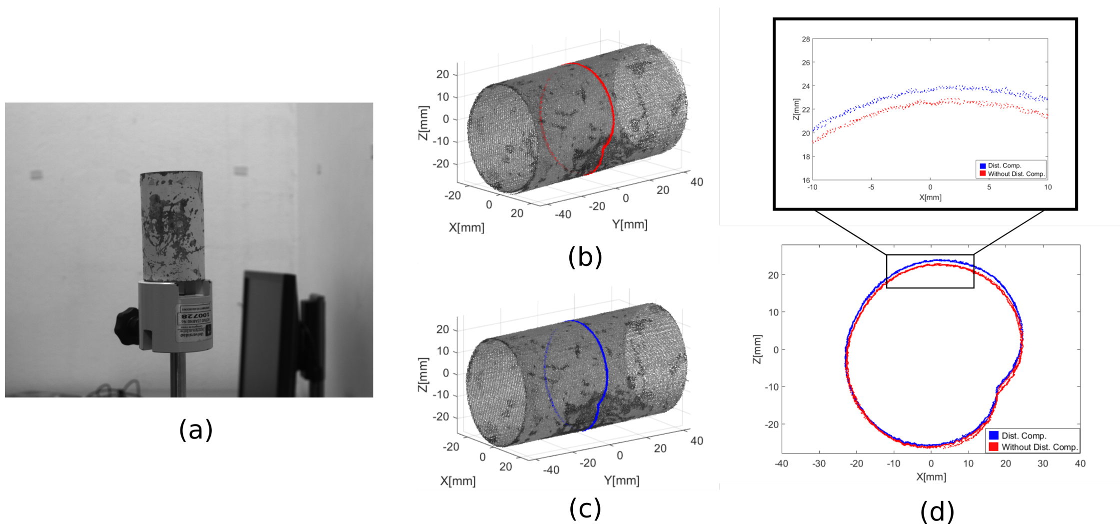

Fig. 2. (a) Dented pipe, (b) 360° 3D reconstruction without geometric distortion compensation, (c) with compensation, and (d) profile comparison.

## 3. Conclusions

In this work we have presented a study on the influence of camera-projector lens distortions for fringe projection profilometry. Our results show that the lens distortion compensation cannot be disregarded, as is often the case, and that the compensation is required for stitching partial 3D reconstructions for building accurate 360° reconstructions.

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