



11–12 October 2012, Riga

**Riga Technical University
53rd International
Scientific Conference**

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On Criteria for Wide-angle Lens Distortion Correction for Photogrammetric Applications

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Keywords – photogrammetry, camera calibration, image distortion, wide-angle lens, correction.

I. INTRODUCTION

Photogrammetry is intensively used both in industrial applications and medicine. Extraction of various anthropometrical data, such as height, shoulder inclination or Kobb angle from single photograph could be implemented in mobile devices, used for health screening. To be able to get photo of standing individual when the space for observations is restricted, wide – angle lens has to be used. Unfortunately, such lenses demonstrate highly expressed radial distortion, thus image has to be corrected before it could be used for estimation the subject's dimensions. There are number of methods, proposed to correct lens radial distortion. Most of them use deviation of the imaged straight line from the real straight line as a criterion for image correction. Correction parameters are adjusted to minimize the deviation. This paper demonstrates, that such criterion does not guarantee that error of dimensions measurements will be minimal as well. In the present work, various radial distortion correction methods, including one, introduced by authors, were evaluated, using both straight line deviation and dimension measurement error. Obtained results allowed formulate recommendation for improvement of existing image correction methodology.

II. MATERIALS AND METHODS

Usually a set of calibration images, taken from different angles, is used to account for different perspective distortion, but in the present work the calibration phantom object was maximally accurately positioned in front of the camera to reduce perspective distortion to the negligible value.

The study was carried out, using phantom object - pattern of 2 × 2 mm black points, placed in the nodes of rectangular net with cell size 10 × 10 mm. Alongside, a stand with reference points was constructed to perform evaluation of the measurement accuracy from a longer distance (distance from pattern was 10 cm, but from stand – 110 cm). The stand's width and height approximately corresponds to the more than medium human sizes.

Within this work 10 different parametric distortion functions were summarized and evaluated, because still any universal for all lenses model have not been established. In addition we have introduced a function (1), which resulted from an attempt to combine commonly used polynomial function with some other trigonometric models:

$$r_u = \arctan\left(\frac{1 + K_1 \times r_d^2 + K_2 \times r_d^3}{1 + K_2 \times r_d^3}\right) \times r_d. \quad (1)$$

For corrected image, the coordinates of the calibration pattern points were extracted using center of mass estimation method which provided sub-pixel resolution in evaluation of the point position. Totally 294 points, grouped in 14 horizontal and 21 vertical lines, were extracted. Then, two target values were calculated. The first one was the

parameter of straightness $\sum(\chi^2/l)$ [2]. The second parameter, which we are introducing, was just the standard deviation S of the measured distance between two adjacent points, calculated over all available pairs.

The distortion correction function's parameters were iterated to minimize either first or the second parameter. Obtained parameters were used to correct the image of the stand. Then maximal deviation from known distances between stand marker sizes ($V = 40$ cm, $H = 20$ cm) was determined and used as parameter of the measurement accuracy.

III. RESULTS AND DISCUSSION

For the group of functions with different measurement errors Δ parameter $\sum(\chi^2/l)$ appeared to be the same that have demonstrated poor usability of this criterion for the selection of the best method. Moreover, the parameter $\sum(\chi^2/l)$ is noticeably higher for cases of low measurement errors.

The proposed distortion correction approach also directly includes determination of the center of distortion.

The last question of interest for the present work was distribution of the distance measurement error over the image plane. For all methods, the distribution of the errors over the image was the same – overestimation of the distances in the bottom – right corner and underestimation in the upper – left corner of the image.

IV. CONCLUSIONS

In the present work, one has demonstrated that widely used criteria of the line straightness do not perform well for the wide–angle lens radial distortion correction. Alternative criteria, based on the minimization of the error of the distance measurement Δ , could be more useful for photogrammetry purposes.

New, Trigonometric-Polynomial radial distortion correction function was introduced. This function demonstrates good characteristics and it have reached highest measurement accuracy for the lens – camera combination, used in the present work.

For the used camera (DMK 31BU03), method allowed to achieve distance measurement precision of about 2%. This result is sufficient for anthropometrics measurements. Besides, only central part of the camera field of view has to be used, since at the image periphery relative error increases up to 15%

Although proposed optimization parameter and correction method has shown good results for the used lens – camera combination, further research in needed to evaluate method's performance for other lenses.

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