Calibration of Convex Lenses with 2nd Order Radial Distortion Model

Rihab K. Hamad  Sinan M. Abdul-Sattar  Razi J. Al-azawi

Abstract— Geometric camera calibration, additionally alluded to as camera re-sectioning, evaluating the parameters of a lens and picture sensor of a picture. Camera parameters can be utilized to correcting the distortion, and measuring the object size in world unit, or knowing the camera position in the scene. Zhang's calibration method is utilized, the method require a chessboard planner with resolution 1830×1330 pixels to be observed from different orientations and translations also using 2nd order radial distortion of the polynomial expression.

The result shows that lens of longer focal length generate low distortion and it is the better lens as contain minimum value of SSE equal to 3.96426 pixels. 

Index Terms— Lenses, Radial distortion, Calibration, Camera parameter

I. INTRODUCTION

In PC vision applications the calibration is a basic stride in quantitative image examination.

In order to extract data from image it is important to know how a point in the scene is anticpated onto the image sensor. Basically the objective of calibration process is to distinguish the camera model which precisely portrays how objects in the 3D world are anticipated onto the 2D picture sensor.

At the present many distortion models and trials are available for evaluating camera lens distortion. Choosing the right model and trials could provide accurate result. The simpler methods which used by the computer vision community have been developed due to the complexity of the evaluation trials and advances in the use of computers for analytical analysis [1-3].

The most well-known calibration techniques take a few pictures of a known object from various camera positions. The projection of calibration object’s components onto the image sensor is approximated with the pinhole model [3-4].

The vast majority of these techniques necessitates either earlier information of some camera parameters or is confined to typical cameras with point of view projections. Thus these techniques cannot be utilized on cameras without knowing the parameters or on camera frameworks which are outfitted with wide-angle or fish-eye.

Cameras with wide-angle and fish-eye shows huge measure of lens distortion which must be given exceptional thought. Much research has been made in the region of distortion calibration on wide-angle [5-6]. Huge numbers of these techniques utilize calibration patterns [7-9], while other nonmetric techniques rely on upon the attendance of certain features in the scene [2, 8-10]. The limitation of the greater part of these strategies is that they are interested in modifying the distortion and leaving parameters (intrinsic and extrinsic) to be evaluated with different strategies.

In this paper radial distortion of the polynomial expression is depended with four convex lenses of different focal length.

Camera lens distortion is important in medium to wide angle lenses. At present many distortion models and trials are available for evaluating camera lens distortion. Choosing the right model and trials could provide accurate result. Simpler methods used by the computer vision community, have been developed due to the complexity of the evaluation trials and advances in the use of computers for analytical analysis [1, 2, 3].

The distortion parameters (k) are calibrated with camera model parameters (intrinsic and extrinsic parameter) [4]. Some methods require metric information around the image scene. Furthermore, between the internal and external parameters of the camera, some kinds of connection happen that produce high errors on the internal parameters [5, 9].

Also, another non-metric method which doesn’t depend on identified scene points has been offered [5, 6, 7, 8, and 9]. Numerous of these methods depend on the fact that the scene straight lines have to project always to the image straight lines. Numerous PC vision algorithms critically depend on the supposition of a linear pinhole camera model, especially those structures from motion algorithms.

The distortion model problems have been addressed by a few approaches that can work on a wide range of cameras. While some of them deliberate an automatic selection approach of distortion model [5, 10].

A parameter-free method was proposed by Hartley and Kang to model distortion which doesn’t depend on any two specific distortion models and it could be applied on fish-eye, wide angle, and normal angle lenses. There are several types of distortion but the most significant type is the radial distortion, especially, in high quality camera that present the error to three dimensions restructure processes which turns straight lines into circular arcs [11, 12]. Straight lines into the world map to straight lines into the image plane could cause in violating the main invariance preserved in the pinhole camera model. Radial distortion at short focal lengths appears as a barrel distortion, while at longer focal lengths appears as...
pincushion distortion. Because there is no much experience with real cameras that introduce significant tangential distortion, tangential distortion was ignored, like some previous works.

II. METHODOLOGY

Zhang’s calibration method shown in figure 1 was utilized and tested on four convex lenses of different focal length (190 mm, 150 mm, 100 mm and 70 mm) to test the performance of the method. The lens was attached on a Sony G camera with 10x optical zoom and 14.1 megapixel resolution with high-quality still images and video recordings, face detection, 720p HD.

A chessboard planner with resolution 1830×1330 pixels, and point’s corner 8×11=88. The method requires at least three images, for each lens five images were captured at different orientations and translations as shown in figure 2.

The accuracy of calibration is surveyed by comparing the variance between measurement results and their position. The exactness of camera calibration decides the estimation accuracy of the system. The quality of camera calibration result directly affects the final measurement result accuracy [11-12].

III. RESULT AND DISCUSSION

The following polynomial expression that symbolizes the radial distortion model was used in this paper:

\[ r_d = r f(r) = r (1+k_1 r^2+k_2 r^4+\ldots) \]  (1)

Where \(k_1, k_2, k_3,\ldots\) are the distortion coefficients and \(r\) is the radial position of the image points. The calibration was done for the four lenses using the first term of polynomial expression, 2nd order radial distortion model.

The calibration results after optimization for the four lenses using 2nd order radial distortion model are shown in the following tables.

<table>
<thead>
<tr>
<th>Focal Length fc pixel</th>
<th>[3507.79222 3447.24339 ] ± [48.01152 48.38464 ]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Principal point ((u_o,v_o)) pixel</td>
<td>[1966.30760 1883.61027 ] ± [70.06869 72.99608 ]</td>
</tr>
<tr>
<td>Skew alpha_c</td>
<td>[0.00000 ] ± [0.00000 ] \Rightarrow angle of pixel axes = 90.00000 ± 0.00000 degrees</td>
</tr>
<tr>
<td>Distortion coefficient fc pixel</td>
<td>[0.25901 -0.60141 0.04575 -0.03760 0.00000 ] ± [0.04598 0.15791 0.01111 0.00926 0.00000 ]</td>
</tr>
<tr>
<td>Pixel Error err</td>
<td>[2.04594 1.91832 ]</td>
</tr>
</tbody>
</table>
In order to compare the lenses with each other we calculate the sum-square-error (SSE) for different lenses using 2\textsuperscript{nd} order model, as illustrated in table 5.

The table shows that for the used model the lens of focal length 190 mm is the proper lens which generates low-distortion, while lens of focal length 70 mm represent high-distortion.

### IV. CONCLUSION

A calibration calculation of 2\textsuperscript{nd} order radial lens distortion for four lenses was presented. The results showed that the camera parameters focal length, principal point, skew, distortion coefficient and pixel error increases as the lens focal length decrease. That’s leads to as long as the focal length of the lens is high, better result was achieved and this has advantage in different application like medical application, also Smart phone cameras manufacturing. Using a lens with low distortion is better to achieve accurate result in achieving low distortion; the lens of high focal length generates low distortion while of low focal length represent high distortion.

Also using of high order term of polynomial expression could achieve high stability of the calibration process.

### REFERENCES


