Class notes
Updated: April 2020

Radial distortion of lenses

Rigoberto Juarez-Salazar

Objective: Determining the parameters of radial distortion induced by imaging lenses.

Lecture

The Zhang's camera calibration method is one of the most powerful tools in computer vision [1]. This method performs the calibration in two steps.

In the first step, the lens distortion is neglected and the camera is modeled as a pinhole. Several homographies can be computed using a planar calibration checkerboard. Then, from the obtained homographies, the intrinsic and extrinsic parameters of the pinhole camera are estimated [2, 3].

In the second step, the camera model is generalized to include the distortion induced by the imaging lens of the camera. A nonlinear camera model is obtained as a result. All the parameters of the camera (intrinsic, extrinsic, and distortion) are estimated by a nonlinear method. The initial estimation from the first step is used as the initial guess for the nonlinear optimization method.

The main advantage of this approach is that the parameter estimation in the first step is a linear optimization problem. Therefore, under proper conditions, the estimation is computationally efficient and the solution is unique.

Considering radial distortion introduces challenging problems. For instance, radial distortion is nonlinear and its estimation is difficult. Moreover, even when the distortion parameters are available, the solution of the model is very difficult when both direct (projection) and inverse (reprojection) processes are necessary to implement. This last issue is evident in applications involving triangulation (such as stereo vision and structured light projection).

The difficulty about lens distortion in the direct and inverse imaging processes occurs because of there is not a simple "clearing procedure" and rational polynomials are involved.

A first solution to this issue is obtained with the radial distortion division model [4]. The division model gives the possibility of keeping a linear camera model even when the radial distortion is included.

In this lesson, the student will apply the division model to generalize the homography-based camera calibration when radial distortion is considered. In laboratory, the student will use a camera with short focal length (3.5 mm or less) to capture a set of phase-shifted gratings displayed on a monitor to get point correspondences. Then the implemented computer routines will be tested. The student will illustrate the usefulness of this topic by displaying distortion-corrected images without perspective.

References

[1] Z. Zhang, "A flexible new technique for camera calibration," IEEE Transactions on Pattern Analysis and Machine Intelligence **22**(11), 330-1334, 2000.

[2] R. Juarez-Salazar and VH. Diaz-Ramirez, "Operator-based homogeneous coordinates: application in camera document scanning" Opt. Eng. **56**(7), 070801, 2017.

[3] R. Hartley, A. Zisserman, Multiple View Geometry in Computer Vision, Cambridge University Press, 2nd Ed., 2003.

[4] A. W. Fitzgibbon, "Simultaneous linear estimation of multiple view geometry and lens distortion," Proc. IEEE Computer Vision and Pattern Recognition, I-125, 2001.