Comparative Analysis of Calibration Methods for a Static Camera

J. Isern González, J.D. Hernández Sosa, A.C. Domínguez Brito and A.M. Naranjo Cabrera

Instituto Universitario de Sistemas Inteligentes y Aplicaciones Numéricas en Ingeniería (IUSIANI)
Universidad de Las Palmas de Gran Canaria
Spain, LAS PALMAS 35017
{jisern, dhernandez, adominguez}@iusiani.ulpgc.es, angel@jqbit.com

Extended Abstract

In computer vision, camera calibration is a procedure that tries to know how a camera projects a 3D object on the screen. This process is necessary in those applications where metric information of the environment must be derived from images. Many methods have been developed in the last few years to calibrate cameras, but very few works (i.e. Tsai [10], Salvi and Armangué [8], Lai [7] or Isern [5]) have been done to compare such methods or to provide the user with hints on the suitability of certain algorithms under particular circumstances.

This work presents a comparative analysis of eight calibration methods for static cameras using a pattern as reference: Faugeras [4], Tsai [9] (classic and optimized version), Lineal, Ahmed [1] and Heikkilä [6] methods, which use a single view of a non-planar pattern; Batista's method [3] which uses a single view of a planar pattern; and Zhang's method [11] which uses multiple views of a planar pattern.

The results provided by every method have been compared and the accuracy in the pattern points reconstruction and the stability of the model parameters when the pattern is relocated or the camera setup varies have been analyzed. We define the stability of a calibration as the constancy of the process results when one parameter changes. Two types of stabilities can be defined: on the one hand, if only extrinsic parameter are varied (pattern location) the values obtained from calibration in the intrinsic parameters (internal setup of the camera) should be constant; on the other hand, if only intrinsic parameters are varied the values obtained from calibration in the extrinsic parameters should be constant.

This study has been carried out with real and simulated images and using, when ever possible, the Matlab code made available by the authors of the methods on the WWW. Different kinds of patterns (planar and non-planar) have been used according to the exigences of each method. Also, the experiments have been repeated using patterns with a different setup; i.e. the number of points and their location have varied. The comparison of the results obtained by every method has been carried out using the same reference images.

Working with real data, only the stability or global errors (2D-Error or 3D-Error) can be studied for each method. We have labelled the mean distance between real and estimated image coordinates and the mean distance between real and reconstructed 3D coordinates of the pattern points, respectively, as the 2D-Error and the 3D-Error.

When the calibration is performed with real data, ground truth values of each parameter of the camera model are unknown so it is impossible to determine that accuracy with which these parameters are obtained. To overcome this difficulty a simulator was developed.

Sensibility to different kind of noises sources has been studied to each method and their results are compared due to the use of the simulator has allowed the analysis of the influence of the determined noise separately of the rest.

The study of the stability of the calibration methods have been realized both in the simulator and in real conditions. In order to analyze the stability of extrinsic parameters a sequence of image was acquired making zoom, therefore the focal length was varied, while the pattern remained static front to the camera. This experiment has been repeated varying the location and setup (number of points) of the pattern.

In order to analyze the stability of intrinsic parameters two types of experiments have been realized. On the first one, the pattern has been displaced parallel to the camera. On the second one, the pattern has been relocated in different positions and distances respect to the camera. In both cases the camera setup remained constant.

The experiments have shown that most of these methods are not stable in the sense that the set of intrinsic parameters returned by a calibration method suffered important variations under small displacements of the camera relative to the calibration pattern. Similar results have been obtained for extrinsic parameters when the camera only changed its internal configuration (i.e. when it zooms in or out) and not its relative position to the calibration pattern. In both cases the instability affects principally to the parameters that are directly related with the element varied in the experiment. Therefore, when focal length varies the pattern distance is very instable and viceversa. Similar results are obtained for optic center when the pattern is displaced parallel to the camera.

On the other hand, the influence of the different types of noise has been study, in concrete, noise in image 2D-coordinates, pattern points 3D-coordinates and distortion of the image. This question has been analyzed only in the simulator due to in real conditions the noises can not be aisled.

The error function minimized by the methods, usually the image disparity (2D-Error), achieves similar error levels with all them, when the experiments have been carried out in the simulator. This happens when the camera setup is near to the ideal, that is to say, when the camera setup is near to guess values introduced to some of the methods, still noise conditions are presented. However, this has not resulted in similar parameter estimations among the methods and, obviously, it has not guaranteed that the parameter estimations converge to the ground truth values.

In general, the experiments have shown that the values of the parameters obtained in the calibration process depend on the method used. In other words, it exists high differences among the estimated value for a determined parameter obtained by each method, still the same image is used as reference to realize the calibration process.

Finally, we can conclude that the review and analysis of the calibration methods considered in this paper have shown that there exists a strong coupling between intrinsic and extrinsic parameters. The main practical implication of this fact is that, when a camera is calibrated with any of these methods, we are "calibrating" the camera with just that pose, as the obtained intrinsic parameters will change with pattern location or camera pose. Hence, the current practice of calibrating a camera that will be moved around, to obtain just its set of intrinsic parameters, must be reconsidered when an accurate calibration is paramount.

References

1. M. Ahmed, E. Hemayed, and A. Farag. Neurocalibration: a neural network that can tell camera calibration parameters. In *IEEE International Conference on Computer Vision*, pages 463–468, September 1999.
2. X. Armangu, J. Salvi, and J. Batlle. A comparative review of camera calibrating methods with accuracy evaluation. In *Proceedings of 5th Ibero-American Symposium on Pattern Recognition, SIARP 2000*, pages 183–194, September 2000.
3. J. Batista, H. Araújo, and A.T. de Almeida. Iterative multi-step explicit camera calibration. In *Proc. Sixth International Conference on Computer Vision ICCV98*, volume 15, pages 709–714, January 1998.
4. Olivier Faugeras. *Three-dimensional computer vision: a geometric viewpoint*. MIT Press, 1993.
5. J. Isern Gonzlez. *Estudio comparativo de mtodos de calibracin y autocalibracin de cmaras*. PhD thesis, University of Las Palmas de Gran Canaria, Las Palmas, Spain, July 2003.
6. J. Heikkila and O. Silvén. A four-step camera calibration procedure with implicit image correction. In *Proc. IEEE Conference on Computer Vision and Pattern Recognition*, volume 1, pages 1106–1112, June 1997.
7. Jim Z.C. Lai. On the sensitivity of camera calibration. *Image and Vision Computing*, 11(10):656–664, December 1993.
8. J. Salvi, X. Armangué, and J. Batlle. A comparative review of camera calibrating methods with accuracy evaluation. *Pattern Recognition*, pages 1617–1635, June 2002.
9. Roger Y. Tsai. A versatile camera calibration technique for high-accuracy 3d machin vision metrology using off-the shelf tv cameras and lenses. *IEEE Journal of Robotics and Automation*, RA-3(4):323–344, August 1987.
10. Roger Y. Tsai. Synopsis of recent progress on camera calibration for 3d machine vision. *The Robotics Review*, pages 147–159, 1989.
11. Zhengyou Zhang. A flexible new technique for camera calibration. *IEEE Transactios on Pattern Analysis and Machine Intelligence*, 22(11):1330–1334, November 2000.