XI JORNADA DE JÓVENES INVESTIGADORES DEL I3A

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Parallel Lines for Calibration of Non-Central Conical Catadioptric Cameras

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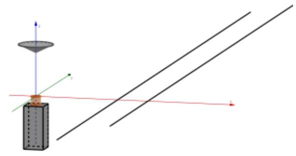
Abstract

In this paper we propose a new calibration method for non-central catadioptric cameras that use a conical mirror. This method consists of using parallel lines, extracted from a single omnidirectional image, instead of using the typical checkerboard to obtain the calibration parameters of the system.

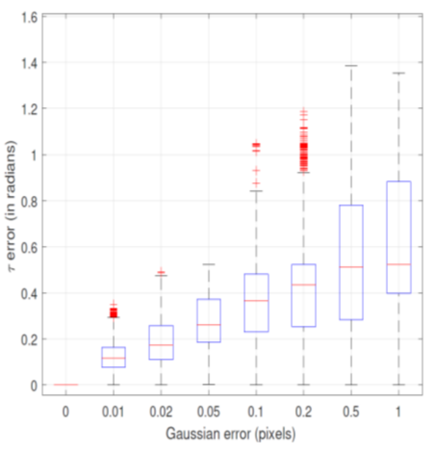
Introduction

Image projection in Non-Central Catadioptric Systems [1], [2] differs a lot from Central Catadioptric Systems [3]. In our case, we work with those Non-Central who make use of a conical mirror, whose projective geometry has been previously studied in [4] (with the Unitary Torus Model), whose position is conditioned by the aperture angle of the mirror, explained in [5].

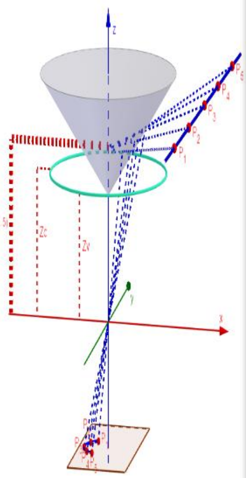


Parallel lines in front of a Conical Catadioptric System.

Synthetic Images with Parallel lines.



Aperture angle (τ) error (in pixels) in function of the applied Gaussian Noise.



Projection of a line in Conical Catadioptric System.

Calibration Method

The first step is to identify two parallel lines within the omnidirectional 2D image, then we take at least five points from each one of them to start with their respective adjustment.

$$\rho_j = -\hat{r}_{i,j} pinv\left(\hat{r}_{i,j}\hat{x}_{n(i,j)}, \hat{r}_{i,j}\hat{y}_{n(i,j)}, \hat{r}_{i,j}^2, \hat{x}_{n(i,j)}, \hat{y}_{n(i,j)}\right),$$

for $i = 1..5$, and $j = 1..2$

Introducing f in this equation we have:

$$\rho_j = \begin{pmatrix} \rho_{j,1} \\ \rho_{j,2} \\ \rho_{j,3} \\ \rho_{j,4} \\ \rho_{j,5} \\ \rho_{j,6} \end{pmatrix} = \begin{pmatrix} \frac{1}{f^2}\left(\frac{(1-cos2\tau)}{cos2\tau} Z_v l_{j,2} - \bar{l}_{j,1}\right) \\ -\frac{1}{f^2}\left(\frac{(1-cos2\tau)}{cos2\tau} Z_v l_{j,1} + \bar{l}_{j,2}\right) \\ \bar{l}_3 tan2\tau \\ tan2\tau\left(\bar{l}_1 + Z_v l_2\right) \\ tan2\tau\left(\bar{l}_2 - Z_v l_1\right) \\ \bar{l}_3 \end{pmatrix}$$

Then solving our system of equations, we get the line L_j (in function of ρ_j) in Plücker coordinates.

$$L_j = \begin{pmatrix} l_{j,1} \\ l_{j,2} \\ l_{j,3} \\ \bar{l}_{j,1} \\ \bar{l}_{j,2} \\ \bar{l}_{j,3} \end{pmatrix} = \begin{pmatrix} -\frac{f^2 sin2\tau\rho_{j,2} + f cos2\tau\rho_{j,5}}{Z_v tan2\tau} \\ \frac{f^2 sin2\tau\rho_{j,1} + f cos2\tau\rho_{j,4}}{Z_v tan2\tau} \\ \frac{f^2 cos2\tau\left(\rho_{j,2}\rho_{j,4} - \rho_{j,1}\rho_{j,5}\right)}{Z_v tan2\tau\rho_{j,6}} \\ \frac{f(1-cos2\tau)\rho_{j,4} - f^2 sin2\tau\rho_{j,1}}{tan2\tau} \\ \frac{f(1-cos2\tau)\rho_{j,5} - f^2 sin2\tau\rho_{j,2}}{tan2\tau} \\ f\rho_{j,6} \end{pmatrix}$$

Now, applying parallelism conditions: $\frac{l_{1,1}}{l_{2,1}} = \frac{l_{1,2}}{l_{2,2}} = \frac{l_{1,3}}{l_{2,3}}$; we get:

$$f tan2\tau = -\frac{\rho_{1,5}\rho_{1,6}(u) - \rho_{2,5}\rho_{2,6}(v)}{\rho_{1,2}\rho_{1,6}(u) - \rho_{2,2}\rho_{2,6}(v)}; \qquad f tan2\tau = -\frac{\rho_{1,4}\rho_{1,6}(u) - \rho_{2,4}\rho_{2,6}(v)}{\rho_{1,1}\rho_{1,6}(u) - \rho_{2,1}\rho_{2,6}(v)};$$

where: $u = \rho_{2,1}\rho_{2,5} - \rho_{2,2}\rho_{2,4}$; $v = \rho_{1,1}\rho_{1,5} - \rho_{1,2}\rho_{1,4}$

Also, from ρ_1 and ρ_2 we can deduce: $\frac{\rho_{j,3}}{\rho_{j,6}} = \frac{tan2\tau}{f}$

Acknowledgments

This work was supported by project RTI2018-096903-B-100 (MINECO/FEDER, UE), and the government of Panamá under the IFARHU–SENACYT scholarship program for PhD studies.

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References

[1]. BERMÚDEZ-CAMEO, J., LÓPEZ-NICOLÁS, G. and GUERRERO, J. J. Fitting line projections in non-central catadioptric cameras with revolution symmetry.
[2]. AGRAWAL, A., TAGUCHI, Y. and RAMALINGAM, S. Analytical forward projection for axial non-central dioptric and catadioptric cameras.
[3]. BARRETO, J. P. and ARAUJO, H. Geometric properties of central catadioptric line images and their application in calibration.
[4]. LÓPEZ-NICOLÁS, G. and SAGÜÉS, C. Unitary torus model for conical mirror based catadioptric system.
[5]. BAKER, S. and NAYAR, S. K. A theory of single-viewpoint catadioptric image formation.

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