A Generic Camera Calibration Method for Fish-Eye Lenses

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23rd August 2004

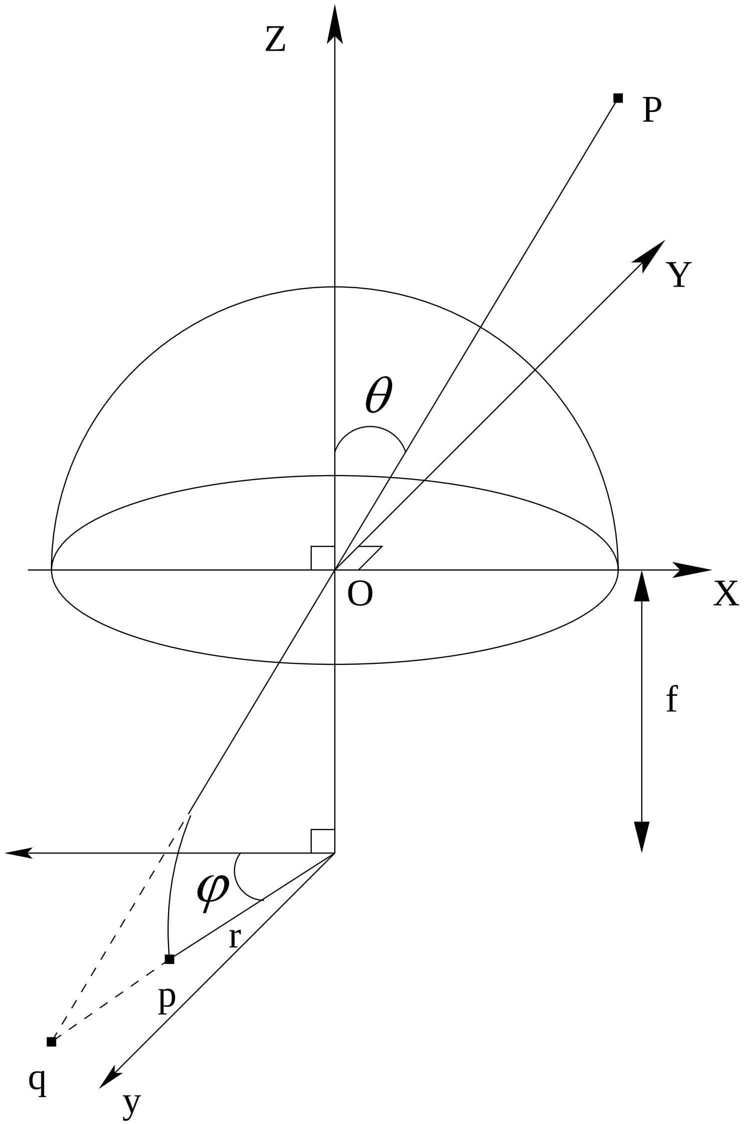
Problem

- the lack of an accurate, generic and easy-to-use calibration procedure for fish-eye lens cameras

Fish-Eye Lens Cameras

- fish-eye lenses have a very wide field of view, about 180°
- the usual pinhole camera model is not suitable for fish-eye lens cameras

Difference between a Pinhole Camera and a Fish-Eye Lens Camera



Camera Projections

- perspective projection

$$r = f\ \tan(\theta) \qquad (1)$$

- fish-eye projections

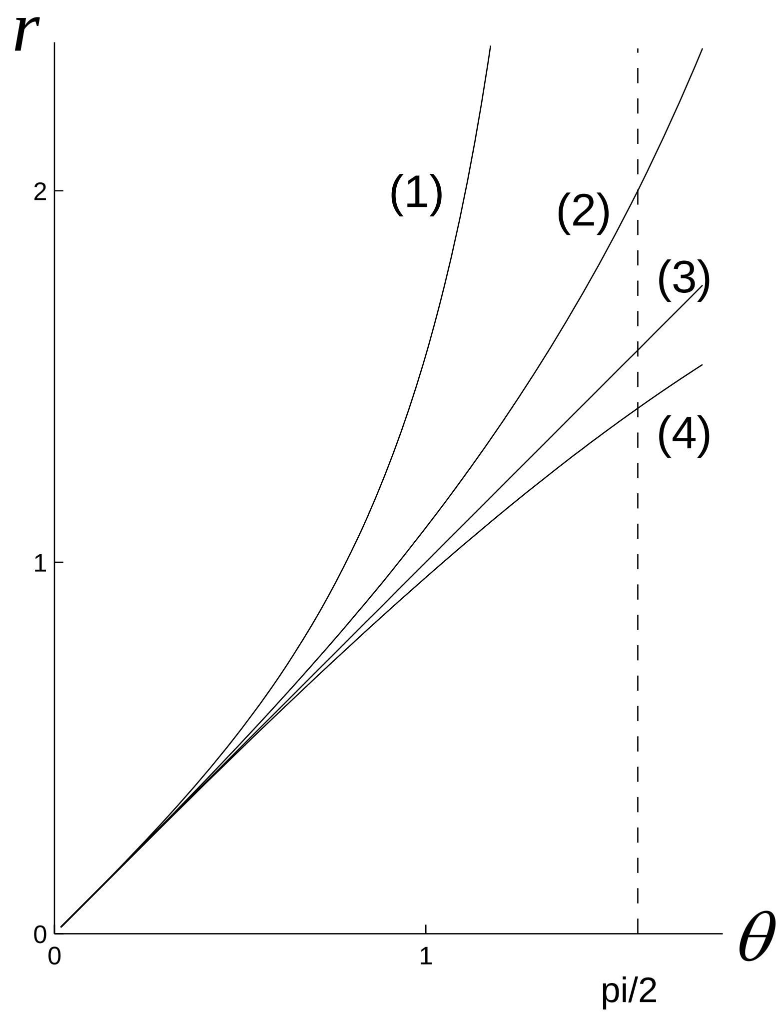
$$r = 2f\ \tan(\theta/2) \qquad (2)$$

$$r = f\theta \qquad (3)$$

$$r = 2f\ \sin(\theta/2) \qquad (4)$$

- a general model

$$r = k_1\theta + k_2\theta^3 + k_3\theta^5 + \dots$$



A Generic Camera Model

- radially symmetric model

$$\begin{pmatrix} x \\ y \end{pmatrix} = r(\theta) \begin{pmatrix} \cos(\varphi) \\ \sin(\varphi) \end{pmatrix}$$

and an additional affine transformation to pixel coordinates

$$\begin{pmatrix} u \\ v \end{pmatrix} = \begin{bmatrix} m_u & 0 \\ 0 & m_v \end{bmatrix} \begin{pmatrix} x \\ y \end{pmatrix} + \begin{pmatrix} u_0 \\ v_0 \end{pmatrix}$$

Extended Model with Distortion

- two asymmetric distortion terms are added

$$\begin{pmatrix} x \\ y \end{pmatrix} = r(\theta)\overline{u}_r(\varphi) + \Delta_r(\theta,\varphi)\overline{u}_r(\varphi) + \Delta_t(\theta,\varphi)\overline{u}_\varphi(\varphi),$$

where

$$\Delta_r(\theta,\varphi) = \left(l_1\theta + l_2\theta^3 + l_3\theta^5\right) \cdot \left(i_1\cos(\varphi) + i_2\sin(\varphi) + i_3\cos(2\varphi) + i_4\sin(2\varphi)\right)$$

and

$$\Delta_t(\theta,\varphi) = \left(m_1\theta + m_2\theta^3 + m_3\theta^5\right) \cdot \left(j_1\cos(\varphi) + j_2\sin(\varphi) + j_3\cos(2\varphi) + j_4\sin(2\varphi)\right)$$

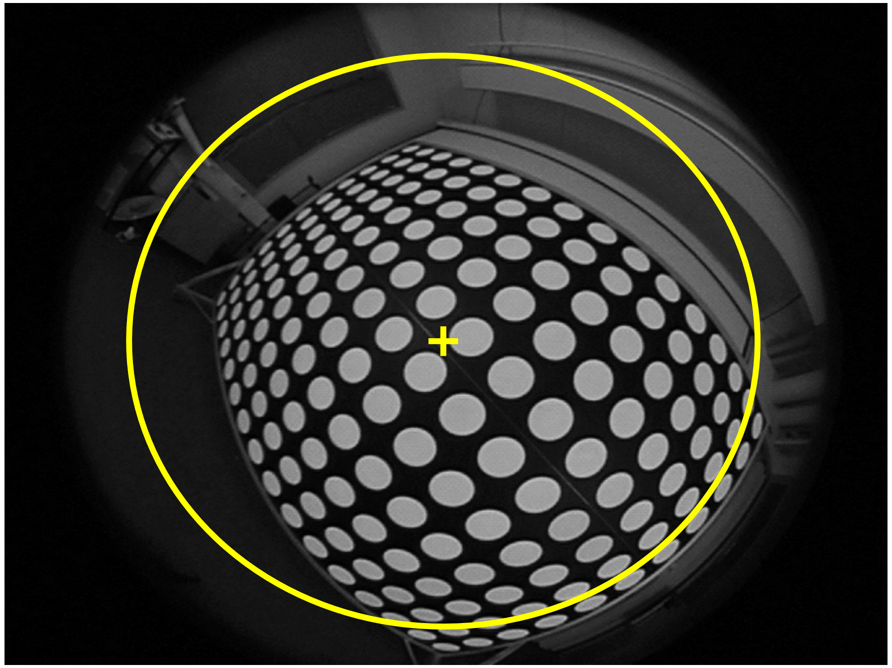
Camera Calibration

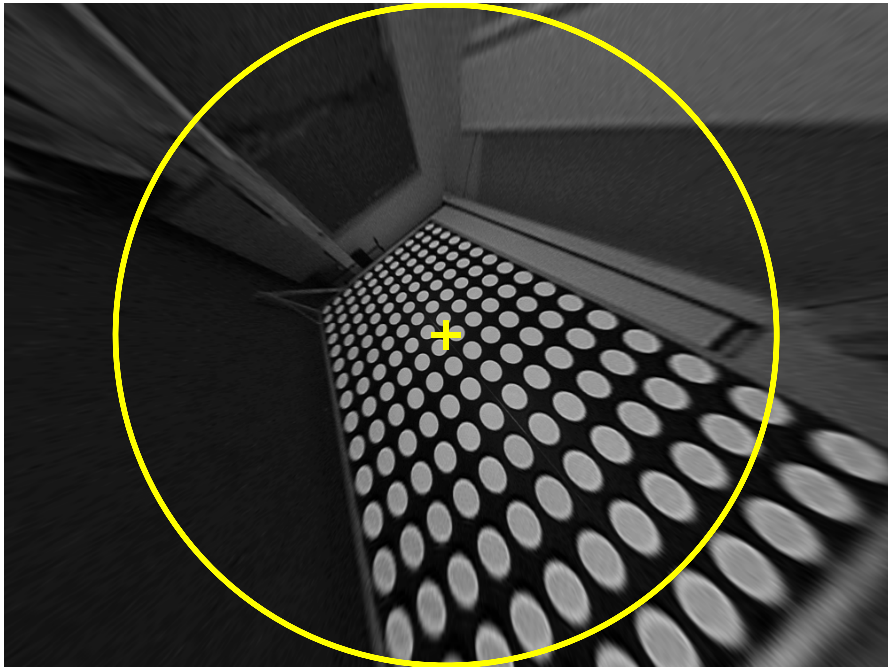
- the camera parameters are determined by viewing a calibration plane which contains control points in known positions
- the optimal way is to minimise the sum of squared distances between the measured and modelled control point projections

Calibration Procedure

- a four step procedure for solving the minimisation problem
  1. initialisation of internal parameters
  2. refinement of the internal parameters by requiring that the mappings between the ”corrected” calibration images and the calibration plane are homographies
  3. initialisation of external parameters
  4. minimisation of projection error

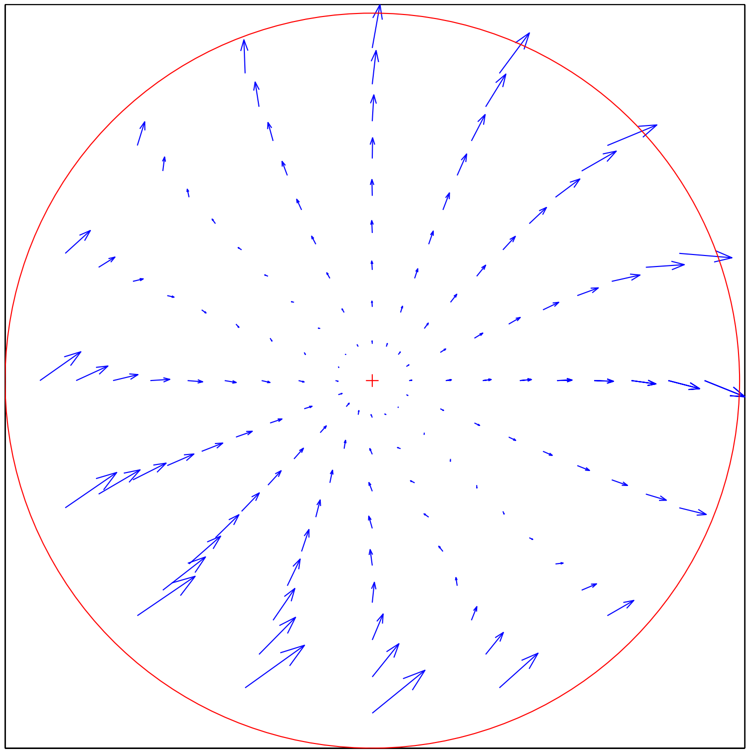
Calibration Using One View

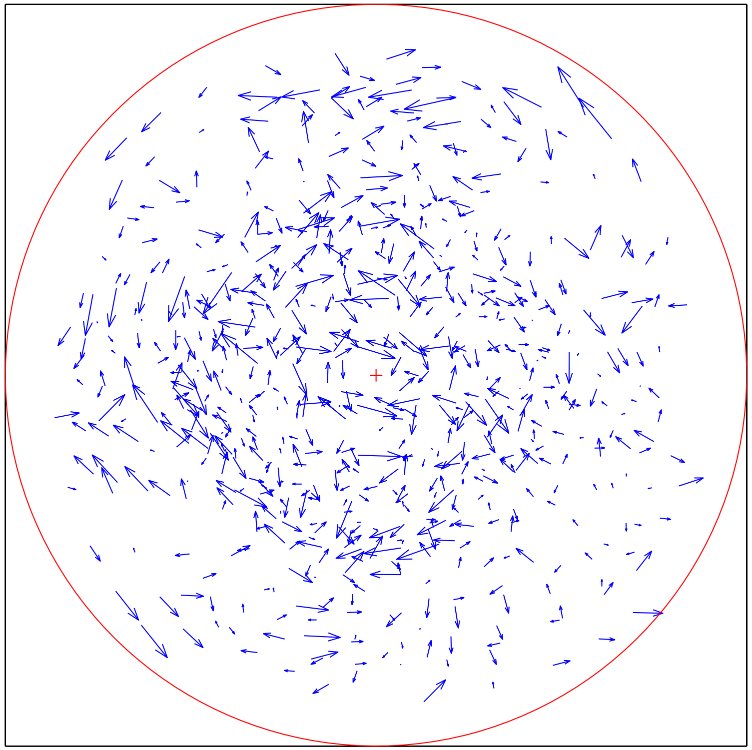




Calibration Using Several Views

	p_6	p_9	p_{23}
σ_u [pix]	0.11	0.074	0.069
σ_v [pix]	0.10	0.060	0.058





Conclusions

- a generic and easy-to-use calibration method was proposed for fish-eye lens cameras
- the proposed camera model is suitable also for conventional cameras
- the method provides for a relatively high level of accuracy by using circular control points