Lab2:- Calibration of a Single Camera

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1 Introduction

The main objective of the lab was to use techniques to calibrate a single camera, by obtaining both its internal parameters and its external parameters respect to a world reference or respect to another camera.

2 Camera calibration using Zhang's method (1999)

The objective of Zhang's method is to obtain the parameters of the camera from mxn correspondences , (i = 1,..., n), (j = 1,...,m with m ¿ 3) , where n points from m images of a planar pattern are used. The advantage of this method is that it allows us to calibrate a camera from a flat pattern without the need to obtain real measurements of the position of 3D points.

2.1 Exercise 1: Computation of the planar homographies

This method is based on obtaining the homographies H(j) that relate 3D points, M(ij) , of a flat pattern with different orientations (j = 1,...,m with m ¿ 3) with their corresponding projections in the image plane, m(ij) = H(j) M(ij).The method assumes that the coordinate system of the 3D world is chosen so that its XY plane coincides with the plane of the pattern, so that the 3D points will all have coordinate Z = 0.

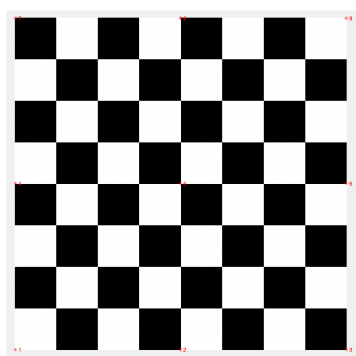

Figure 1: Image of the original pattern with the selected points.

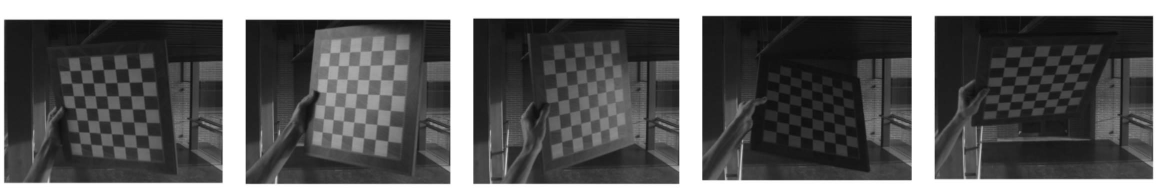

Figure 2: The given captured images,for 5 different pattern orientations.

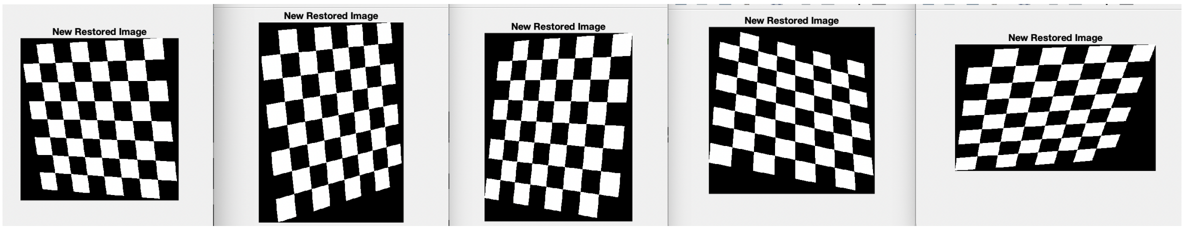

Figure 3: The results obtained after applying homography to each of the original pattern.

2.2 Exercise 2: Computation of the internal and external parameters

Firstly, we calculate the matrix of internal parameters A of the camera from the homographies obtained in the previous exercise. The procedure proposed by Zhang is based on the establishment of two relations between the homography that transforms a flat pattern into the image plane and the conic coefficient matrix B that defines the Image of the Absolute Conic (IAC).

Number of pattern Images	**3**	**4**	**5**
Scale factor for the U axis (a)	1739.0409	1828.9983	1858.4352
Scale factor for the V axis (b)	1762.6908	1817.6144	1837.252
U0 coordinate of principal point	473.1102	489.7487	498.8634
V0 coordinate of principal point	319.9132	348.3546	336.4197
Angle, in degrees, between the image axes	89.55	89.52	89.55

Figure 4: The internal parameters using original homography matrix,for 5 different pattern orientations.

Number of pattern Images	**3**	**4**	**5**
Scale factor for the U axis (a)	1732.39557	1829.937	1853.7455
Scale factor for the V axis (b)	1756.9925	1816.5729	1831.832
U0 coordinate of principal point	475.3978	493.6777	503.6028
V0 coordinate of principal point	319.9428	350.8918	340.4696
Angle, in degrees, between the image axes	89.205	89.322	89.27

Figure 5: The internal parameters using modified homography matrix,for 5 different pattern orientations.

$$\text{Rotational and Transnational Matrix for 1st orientation} \begin{bmatrix} -0.8684 & -0.1108 & 0.4832 & 164.5020 \\ 0.0026 & -0.9757 & -0.2190 & 105.1375 \\ 0.4957 & -0.1889 & 0.8476 & -1236.548 \end{bmatrix}$$

$$\text{Rotational and Transnational Matrix for 2nd orientation} \begin{bmatrix} -0.7567 & -0.08313 & -0.6483 & 71.3185 \\ 0.1339 & -0.9905 & -0.0293 & 126.4104 \\ -0.6397 & -0.1090 & 0.7607 & -1099.4385 \end{bmatrix}$$

$$\text{Rotational and Transnational Matrix for 3rd orientation} \begin{bmatrix} -0.7163 & 0.1107 & 0.6888 & 48.6083 \\ -0.03198 & -0.9915 & 0.12609 & 158.5596 \\ 0.6969 & 0.06830 & 0.71385 & -1215.8292 \end{bmatrix}$$

Rotational and Transnational Matrix for 4th orientation $\begin{bmatrix} -0.9353 & 0.0097 & -0.35360 & 116.3052 \\ -0.2279 & -0.78103 & 0.5814 & 93.1021 \\ -0.2705 & 0.62440 & 0.7327 & -1382.4264 \end{bmatrix}$

Rotational and Transnational Matrix for 5th orientation $\begin{bmatrix} -0.9498 & 0.19770 & -0.24236 & 126.0507 \\ 0.05808 & -0.64993 & -0.7577 & 108.0784 \\ -0.3073 & -0.7338 & 0.6058 & -1039.5704 \end{bmatrix}$

2.3 Exercise 3: Calibration of the camera of a mobile device

In this exercise we are calibrating the cameras of mobile phones using five images of the pattern taken in different orientations of the 3D space (pan, tilt, roll). The actual dimensions of the pattern is 500X500mm.

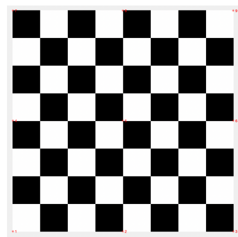

Figure 6: Image of the original pattern with the selected points.

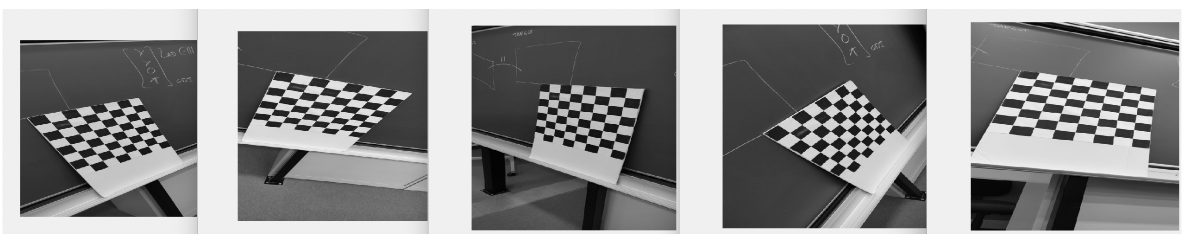

Figure 7: The captured images,for 5 different pattern orientations.

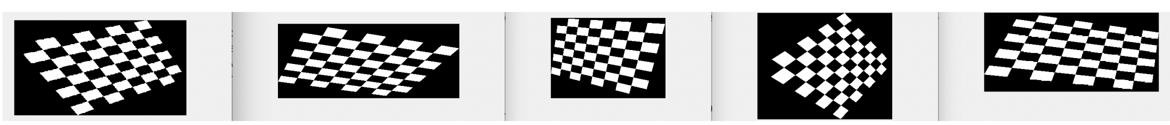

Figure 8: The results obtained after applying homography to each of the original pattern.

The internal parameters using different camera orientations are mentioned in 1able 1.

Number of pattern Images	3	4	5
Scale factor for the U axis (a)	779.0085	792.2522	849.1596
Scale factor for the V axis(b)	353.3692	360.3093	369.3531
U0 coordinate of principal point	259.852	259.0456	273.445
V0 coordinate of principal point	228.9615	229.5733	254.2635
Angle,in degrees between the image axes	89.9	90.06	91.39

Table 1: The internal parameters using different camera orientations.

2.4 Exercise 4: Calculation of the relative position between cameras

In the task i couldn't arrange three different cameras. So, i took three images in different orientation from the same camera. Using the three different images trying to calibrate the camera.

Internal parameter matrix for the camera used to capture same image using three different orientations

$$A=\begin{bmatrix} 849.15969 & -20.7271 & 273.4450 \\ 0 & 369.35310 & 254.2635 \\ 0 & 0 & 1 \end{bmatrix}$$

Internal parameters (A)	MAT A	MAT A	MAT A
Camera position t=[tx,ty,tz]	[0,0,0]	NA*	NA*
Estimated position t=[tx,ty,tz]	[0,0,0]	[68.10,-329.99,97.19]	[117.42,-319.16,387.84]
Camera orientation=[ax,ay,az]	[0,0,0]	NA*	NA*
Estimated orientation=[ax,ay,az]	[0,0,0]	[18.54,19.90,44.36]	[3.07,75.93,49.13]

Table 2: The estimated camera position and camera orientation

2.5 Exercise 5: Estimation of the radial distortion

The objective of this exercise is to obtain an estimate of the type and degree of distortion introduced by the camera of the mobile device.

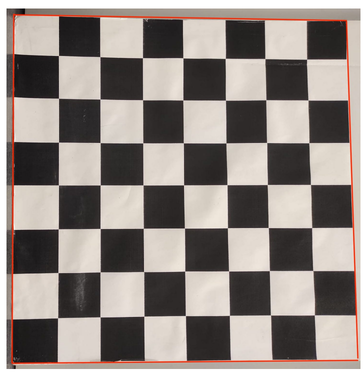

Figure 9: Image to calculate the frontal distortion.

Side:	Left	Right	Top	Bottom
Amount of distortion (1-5)	1	1	1	1
Type of distortion (B or P)	NA	P	P	P

Table 3: Frontal distortion parameters of the camera used.