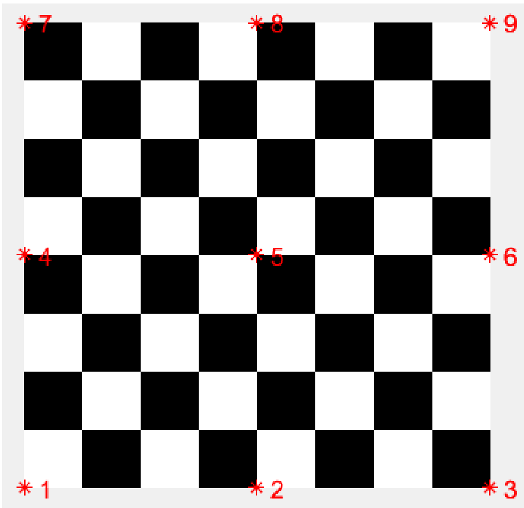
Lab Ass. 2: Calibration of a single camera

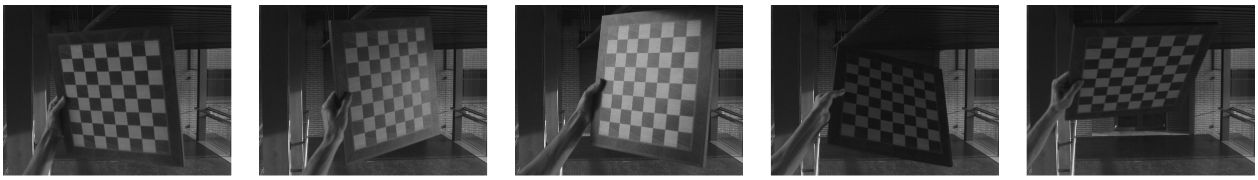
In computer vision, it is often necessary to calibrate a single camera in order to obtain its internal and external parameters with respect to a world reference or another camera.

1. **Exercise: Computation of the planar homographies**

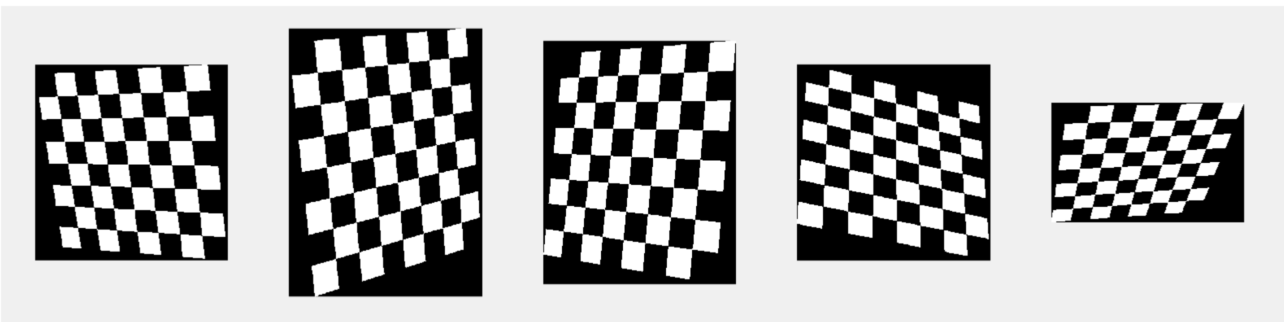
In this exercise I obtained the homographies Hj that transform 3D points of a flat pattern with 5 different orientations to their corresponding projections in the image plane. For this I used the given functions: get_real_points_checkerboard_vmmc, get_user_points_vmmc to get the 9 points indicated in the picture below, homography_solve_vmmc and homography_refine_vmmc.



The original pattern with the selected points



The given images for 5 different pattern orientation



The result images after applying homography

2. Exercise: Computation of the internal and external parameters

I used 3, 4 and 5 homographies, and the results can be seen in the following tables. The ground truth data obtained from the specifications of the camera used in this exercise: b = 1828, u_0 = 512, v_0 = 280. My numbers are calculated from the internal_parameters_solve_vmmc function and from the generated matrix the data can be constructed following the next equations.
From the code the following equations are given:

```
lambda = b(6)-(b(4)^2+v0*bn)/b(1);
alfa = sqrt(abs(lambda/b(1)));          % scale factor for the u axis.
beta = sqrt(lambda*b(1)/bd);            % scale factor for the v axis.
gamma = -b(2)*alfa^2*beta/lambda;       % parameter representing a
non-perpendicular image plane.
u0 = gamma*v0/alfa-b(4)*alfa^2/lambda;  % u0 coordinate of the principal point.
```

```
A = [alfa gamma u0
     0    beta   v0
     0    0      1];
```

Nº of pattern images:	3	4	5
Scale factor for the U axis (a)	1953.7952	1787.4202	1767.8658
Scale factor for the V axis (b)	1899.2309	1799.9081	1792.3019
u_0 coordinate of the principal point	592.8758	550.2642	512.1399
v_0 coordinate of the principal point	390.6014	335.8485	353.8321
Agle, in degrees, between the image axes	48.9634	45.1476	19.8823

The internal parameters using the modified homography matrix

Nº of pattern images:	3	4	5
Scale factor for the U axis (a)	1938.4751	1783.3167	1775.8834
Scale factor for the V axis (b)	1892.4844	1798.839	1801.3859
u_0 coordinate of the principal point	585.2487	546.9453	508.48
v_0 coordinate of the principal point	376.4844	326.0556	341.9019
Agle, in degrees, between the image axes	39.9169	37.7088	8.5411

The internal parameters using the original homography matrix

The calculated rotation and transformation matrix for the first orientation

-0.8986	-0.1052	0.4259	176.3516
0.0089	-0.9750	-0.2220	114.2618
0.4386	-0.1957	0.8771	-1.1888e+03

The calculated rotation and transformation matrix for the second orientation

-0.7572	-0.0750	-0.6489	79.0136
0.1514	-0.9865	-0.0626	130.4124
-0.6354	-0.1456	0.7583	-1.0297e+03

The calculated rotation and transformation matrix for the third orientation

0.7745	-0.1050	0.6238	-60.9914
0.0388	0.9922	0.1188	-173.4989
-0.6314	-0.0678	0.7725	1.2093e+03

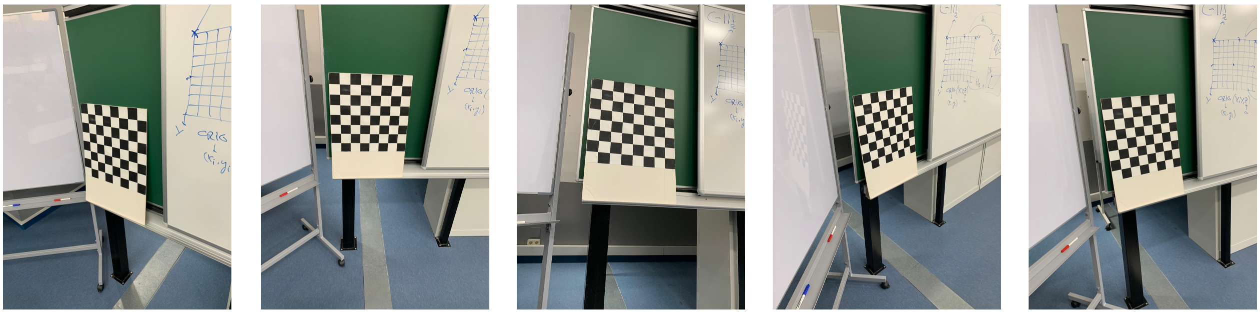
The calculated rotation and transformation matrix for the fourth orientation

0.9457	-0.0109	-0.3250	-124.1228
0.2178	0.7634	0.6082	-99.3606
0.2414	-0.6459	0.7242	1.3449e+03

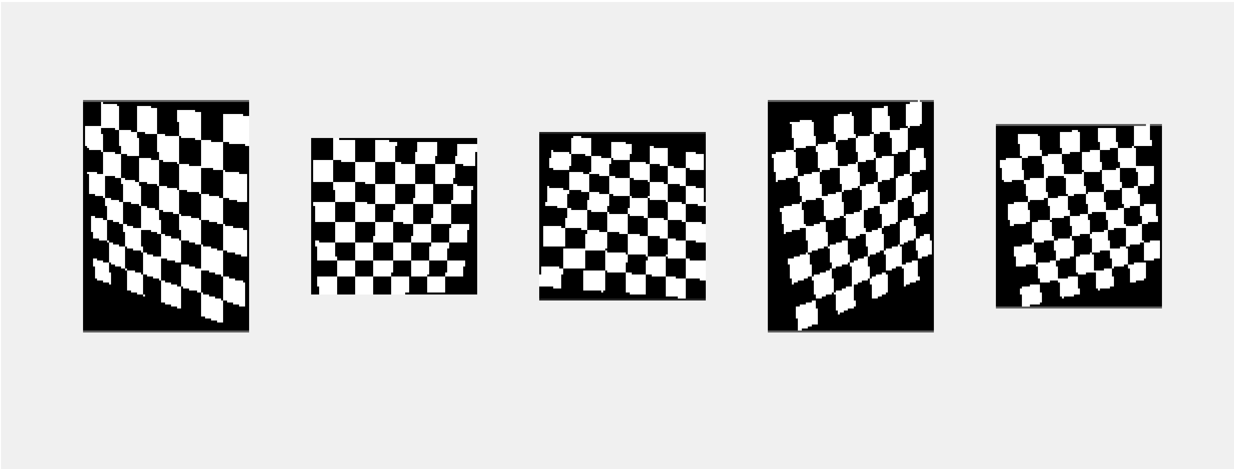
The calculated rotation and transformation matrix for the fifth orientation

0.9604	-0.1811	-0.2117	-135.4161
-0.0450	0.6490	-0.7595	-116.3969
0.2749	0.7389	0.6151	992.9394

3. **Exercise: Calibration of the camera of a mobile device**
   In this exercise I calibrated the camera of my mobile using 5 photos of the patterns in different orientation.



The mobile photos for 5 different pattern orientation



The result images after applying homography

Nº of pattern images:	3	4	5
Scale factor for the U axis (a)	1188.4436	1165.9999	1165.1913
Scale factor for the V axis (b)	1172.1063	1152.0705	1151.6695
u_0 coordinate of the principal point	597.8263	616.7406	615.304
v_0 coordinate of the principal point	819.8115	802.4982	805.7473
Agle, in degrees, between the image axes	14.6771	5.2	10.7939

The internal parameters using the different camera orientations

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I calibrated the relative distance and orientation between three cameras of three mobile phones.

Camera 1	
Camera 2	
Camera 3	

Internal parameter matrices for the cameras

	Camera 1	Camera 2	Camera 3
Internal paramers, A_i	*	*	*
Camera position t = [tx, ty, tz]	[0 0 0]		
Estimated position t = [tx, ty, tz]	[0 0 0]	[748.396917500176 229.821165593032 -3684.50329470097]	[818.090368721327 645.858287191554 -2795.21193471675]
Camera orientation [αx, αy, αz]	[0 0 0]		
Estimated orientation [αx, αy, αz]]	[0 0 0]	[45.4867 25.7123 179.5444]	[44.1846 3.6612 179.7398]

The estimated camera positions and camera orientations

In the estimated orientation tz should be almost the same, just the first phone took the picture upside down.

*

Internal parameters for camera 1:

1644.18833966687 -37.3619909097256 1142.89032557952
0 1602.08201306136 624.745165213021
0 0 1

Internal parameters for camera 2:

1816.50556957162 -26.7314324856174 481.931575172697
0 1783.61948858956 364.526658780321
0 0 1

Internal parameters for camera 1:

3072.33064584233 -4.78495564271752 1701.93735511815
0 2986.31068566594 1910.66861845505
0 0 1

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In this exercise I estimated the type and degree of the distortion of my mobiles camera.

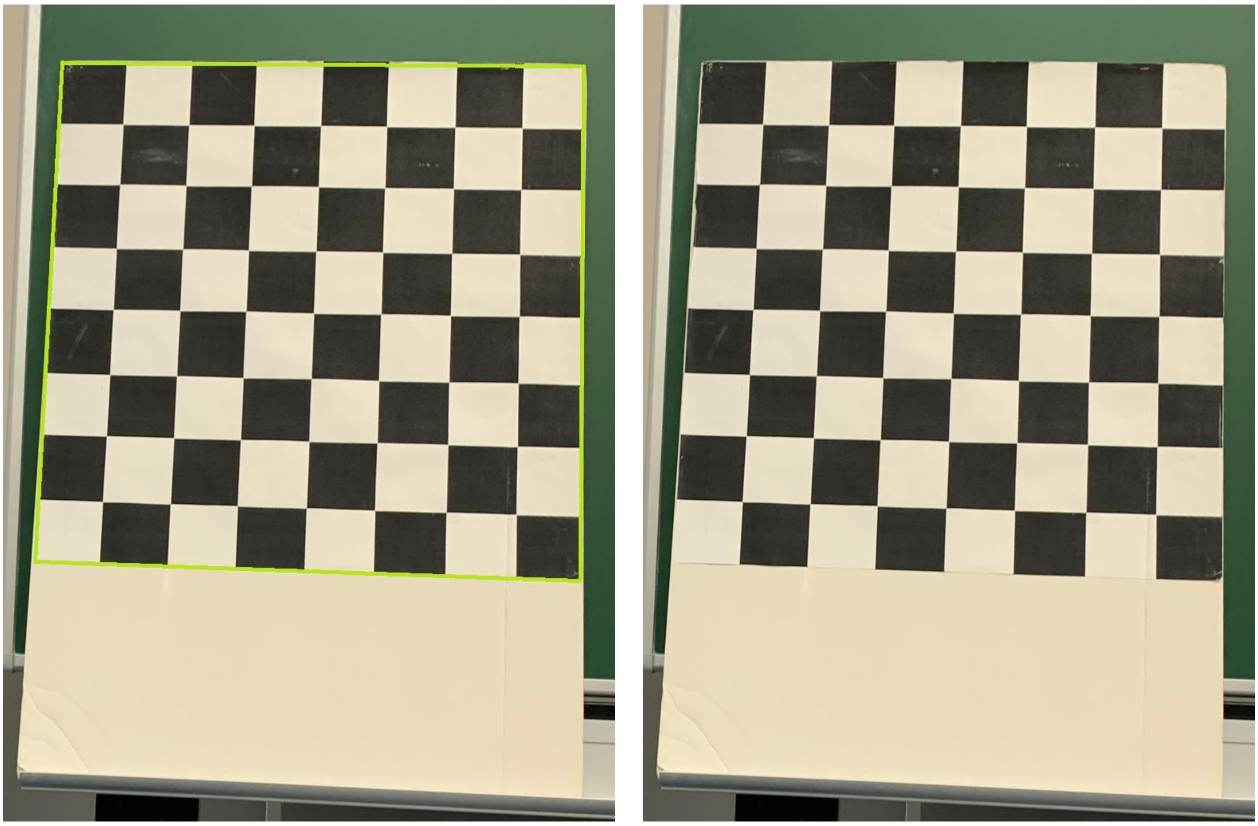

Image to calculate the frontal disorders

Side:	Left	Right	Top	Bottom
Amount of distortion (1 to 5)	**1**	**1**	**2**	**2**
Type of distortion (B or P)	**B**	**B**	**P**	**B**

Disorders parameters of the camera of my mobile