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Reading Assignment

I pledge that I have read the reading material in the assignment.

Calibration using 3D objects.

Part A: Intrinsic parameter calculation

$$K = \begin{bmatrix} \alpha_x & s & p_x \\ & \alpha_y & p_y \\ & & 1 \end{bmatrix}$$

$\alpha_{y=}$3.4289*1.0e+03 = 3428.9
$\alpha_{x=}$3.3863*1.0e+03 = 3386.3
s=0.0127*1.0e+03 = 12.7
P_x=0.8529*1.0e+03 = 852.9
P_y= 0.6275*1.0e+03 = 627.5

Part B: Intrinsic and extrinsic parameter computation

(i) 3D-2D correspondences

(0,3,0,1)=> (586,129,1);(1,3,0,1)=>(756,129,1);(2,3,0,1)=>(938,133,1);(3,3,0,1)=>(1112,133,1)
(0,2,0,1)=>(574,269,1);(1,2,0,1)=>(750,273,1);(2,2,0,1)=>(934,273,1);(3,2,0,1) =>(1112,275,1)
(0,1,0,1) =>(568,425,1);(1,1,0,1) =>(746,429,1)(2,1,0,1) =>(932,435,1)(3,1,0,1) =>(1114,437,1)
(0,0,0,1) =>(552,583,1);(1,0,0,1) =>(732,587,1);(2,0,0,1) =>(930,591,1);(3,0,0,1) =>(1120,599,1)
(0,0, -1,1)=>(566,681,1);(1,0, -1,1)=>(738,683,1);(2,0, -1,1)=>(928,689,1);(3,0, -1,1)=>(1110,687,1)
(0,0, -2,1) =>(580,765,1);(1,0, -2,1) =>(740,769,1);(2,0, -2,1) =>(924,769,1);(3,0, -2,1) =>(1094,775,1)
(0,0, -3,1) =>(590,837,1);(1,0, -3,1) =>(750,841,1);(2,0, -3,1) =>(922,839,1);(3,0, -3,1) =>(1086,849,1)

(ii) The Projection Matrix.

P=	-0.2176	-0.0341	0.0497	-0.6473
	-0.0008	0.1758	0.1469	-0.6910
	0.0000	-0.0000	0.0001	-0.0012

K-R-T values

K= 1.0e+03 *

3.2824	-0.0081	0.6179
0	3.3419	0.5664
0	0	0.0010

R=

0.9964	0.0572	-0.0630
0.0177	-0.8632	-0.5045
-0.0833	0.5016	-0.8611

T= -0.3613
0.1068
17.4189

(iii) Answers

(a)Direct Linear Transformation. DLT is basically used to solve a set of similar equations. But what makes this algorithm different from others is the fact that it can be used to solve over-determined and under-determined equations also. For over determined case it finds the least square solution $||Y\text{-}AX||^2$ using SVD under constraint $||A||=1$.

(b) There are in total 11 D.O.F so the total number of minimal point correspondences needed is equal to 6.

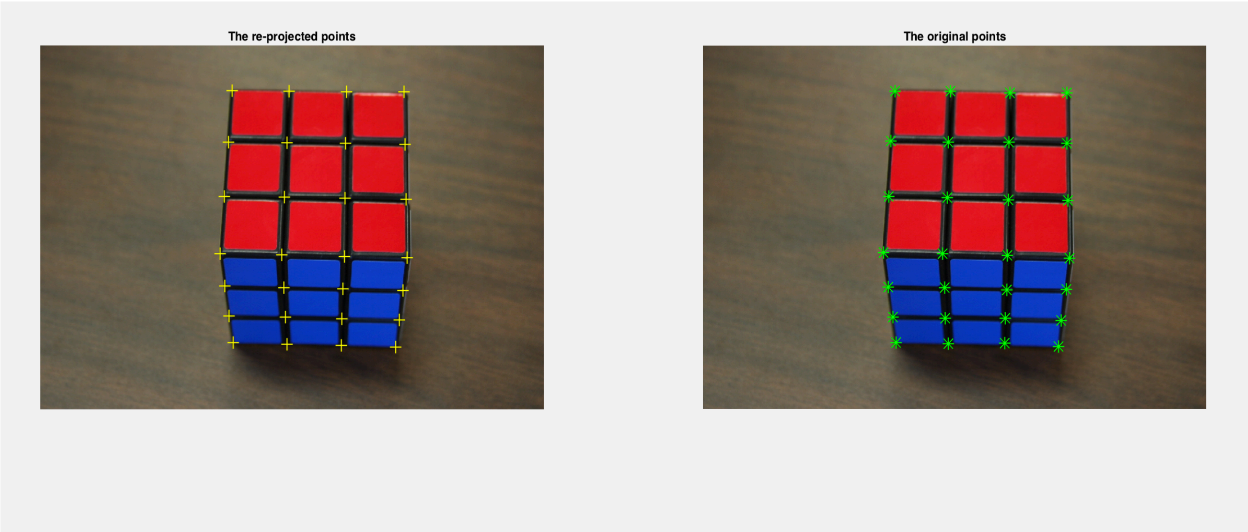
(c) Let us write P = [M p_4], where M is the first 3*3 sub-matrix of P. Now, the expression P = K[R t] implies that M = KR, where K is an upper triangular matrix and R is a rotation matrix. Then we can use QR decomposition to solve for K and R. where R is a orthogonal matrix and K will be the upper triangle matrix after this we can find t as we know P K and R.

(iv)Re-Projection error

$$err = \frac{\sqrt{\sum_{i=1}^{N}(x_i - \hat{x}_i)^2 + (y_i - \hat{y}_i)^2}}{N}$$

The error is err=0.8063.

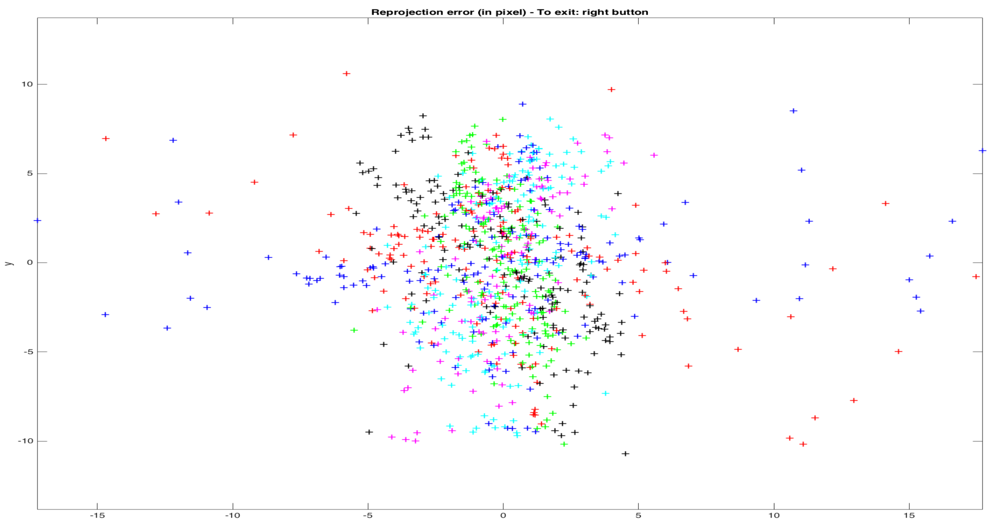
(Fig1- Re-projected points Vs original 2D correspondence points)



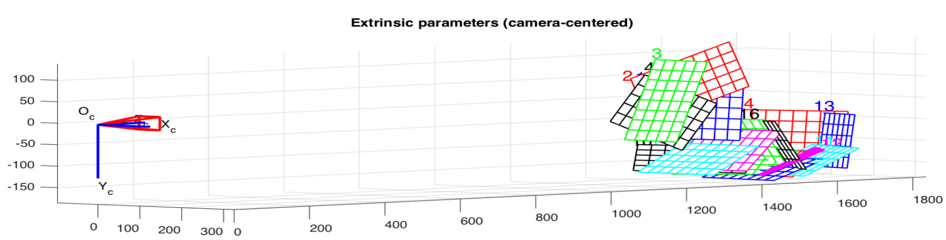
2.Calibration using planar objects.

wintx ([] = 27) = []
winty ([] = 27) = []
Window size = 55x55
Calibration results after optimization (with uncertainties):
Focal Length: fc = [8249.27000 8253.86954] +/- [458.70440 448.97820]
Principal point: cc = [1087.19369 981.00261] +/- [294.30804 216.87098]
Skew: alpha_c = [0.00000] +/- [0.00000] => angle of pixel axes = 90.00000 +/- 0.00000 degrees
Distortion: kc = [1.36306 -9.84662 -0.05595 -0.07548 0.00000] +/- [0.40192 6.03703 0.03602 0.05432 0.00000]
Pixel error: err = [2.69734 3.96910]

(Fig2-Reprojection error with window size 55*55)

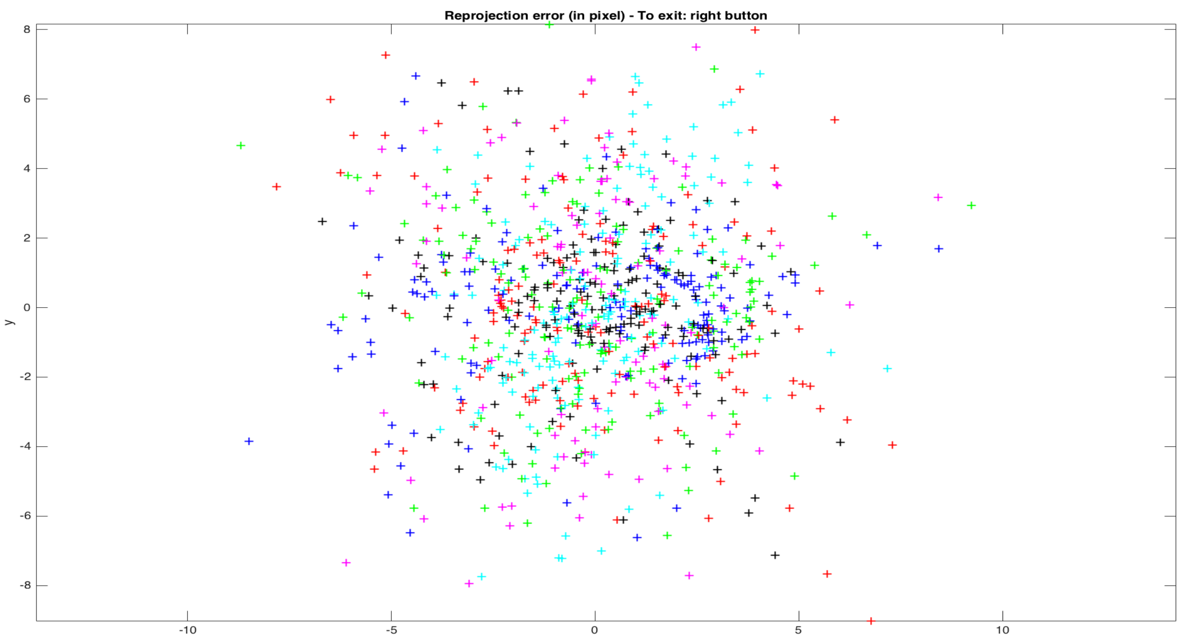


(Fig3-Extrinsic parameter of camera for window size 55*55)

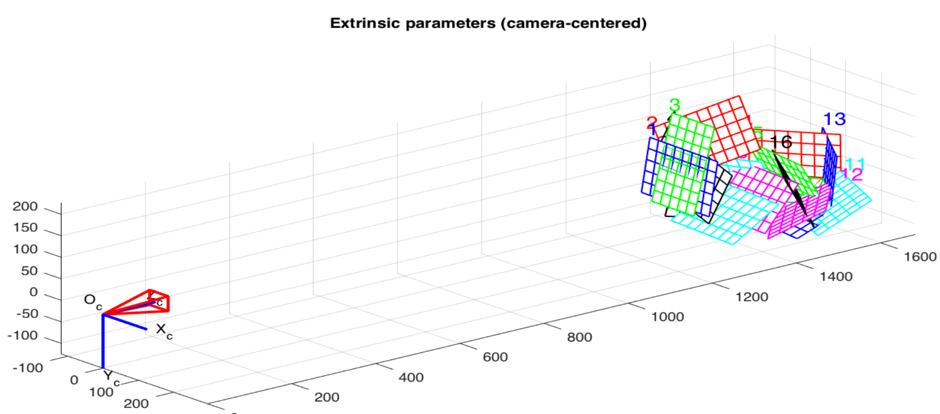


Using (wintx,winty)=(8,8) - Window size = 17x17
Calibration results after optimization (with uncertainties):
Focal Length: fc = [8266.98805 8365.45137] +/- [344.93134 347.61710]
Principal point: cc = [1104.82463 1537.80632] +/- [499.13481 295.67812]
Skew: alpha_c = [0.00000] +/- [0.00000] => angle of pixel axes = 90.00000 +/- 0.00000 degrees
Distortion: kc = [0.71742 -3.41533 -0.00447 -0.04869 0.00000] +/- [0.38264 6.76573 0.02963 0.05983 0.00000]
Pixel error: err = [2.65245 2.77582] (all active images).
The pixel error reduced on changing the window length.

(Fig4-Reprojection error with window size 17*17)



(Fig5-Extrinsic parameter of camera for window size 17*17)



The Principle behind the above Technique.

The main idea is to use 2D metric information rather than 3D which is required if doing photogrammetric calibration due to which normal 2-D planar objects like a chess board can be used and either the plane or the camera be moved to get different orientations. The approach is to obtain a closed form solution and then perform nonlinear refinement based on Maximum Likelihood Estimation criteria.