Problem Statement :

The goal of this assignment is to **find intrinsic and extrinsic camera calibration parameters** of your mobile phone's camera.

Intrinsic calibration parameters include focal length, skew, radial distortion parameters, other distortion parameters, camera's optic center.

Extrinsic calibration parameters include Rotation, Translation (and/or scale) computation for every photo taken by the mobile phone.

The Use case is 2 fold. Indoor scenes and outdoor scenes. Experiments shall be done separately for both data sets which shall be collected by students themselves.

Calculate the error in calibration by computing the average **reprojection error** (in pixels) for all indoor, outdoor and both cases.

Students may use any calibration method for calibrating.

Solution Approach :

1. We have taken **32 points** to ensure better results . The points have been taken in a checkerboard(corner) in order to ensure that the coordinate that we obtain is consistent and easy to obtain .

   The **checkerboard** box **dimensions** are **: 23mm * 23 mm.**

2. For the image pixel corners we have used the below matlab functions :

   ```
   camCordinate = corner(I, 'MinimumEigenvalue', 50, 'QualityLevel', 0.4);
   ```

3. Then we have obtained the corresponding three dimensional coordinates manually knowing the checkerboard dimension.

4. Then we have constructed the homogeneous matrix to obtain the parameters.

   So what we have is Set of Linear Equations of the form :

   $$Ax = 0$$

5. We have used the SVD method to obtained the nearest possible solution. The concept used is as below :

1. To find the solution of Ax = 0
2. We need to find the non-trivial null vector of A.
3. "A" can have up to 12 eigenvalues.
   a) Case 1: If rank(A) is 12, its nullity is zero. There is no non-trivial null vector of A.
   b) Case 2: If rank(A) is 11, it will have exactly one zero eigenvalue and the corresponding
      eigenvector will be the solution of Ax = 0 .
   c) Case 3: If rank(A) < 11, there are infinite solutions to Check if data is degenerate.
      Recalibrate.

Re-projection Error Calculation (in pixels):

1. In order to calculate the reprojection error calculation we selected 4 corner points which have not been used for the extrinsic and Intrinsic parameter calculation .
2. Then we used the calculated parameter matrix to learn the coordinates of those points .
3. Then we calculated the Euclidean distance between them .

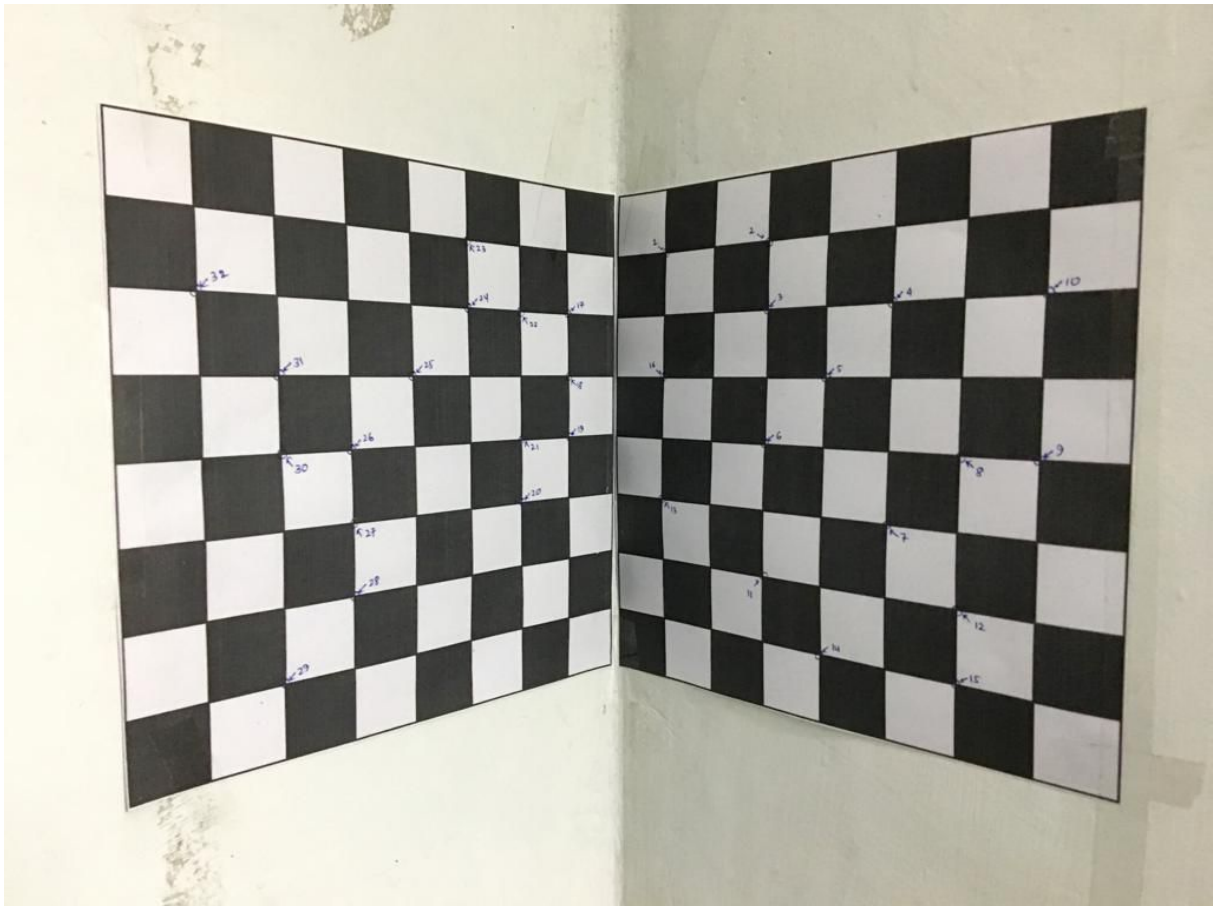
   Eu_distance = sqrt(square(projected_x_index - truth_x_index) + square(projected_y_index - truth_y_index))

4. There average value is the average reprojection error that we mention here for both Indoor and outdoor scenes.

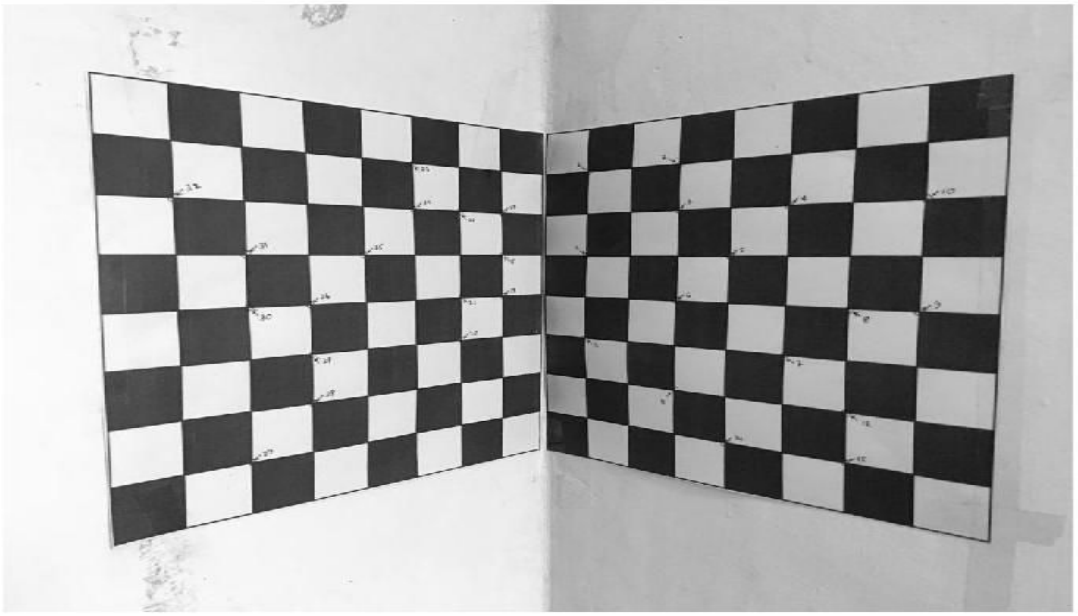
   avg_reprojection_error = totalSum(Eu_distance)/no_of_points

Now we will show the images obtained for both the indoor and outdoor scenes . The Raw images taken from phone camera then the gray level image of the same and then the image which shows the the corner points selected for the camera parameter calculation .
Then we will show the calculated parameters values .
We have also registered the average reprojection error as part of parameters calculated in terms of pixel for both the indoor and outdoor scenes .

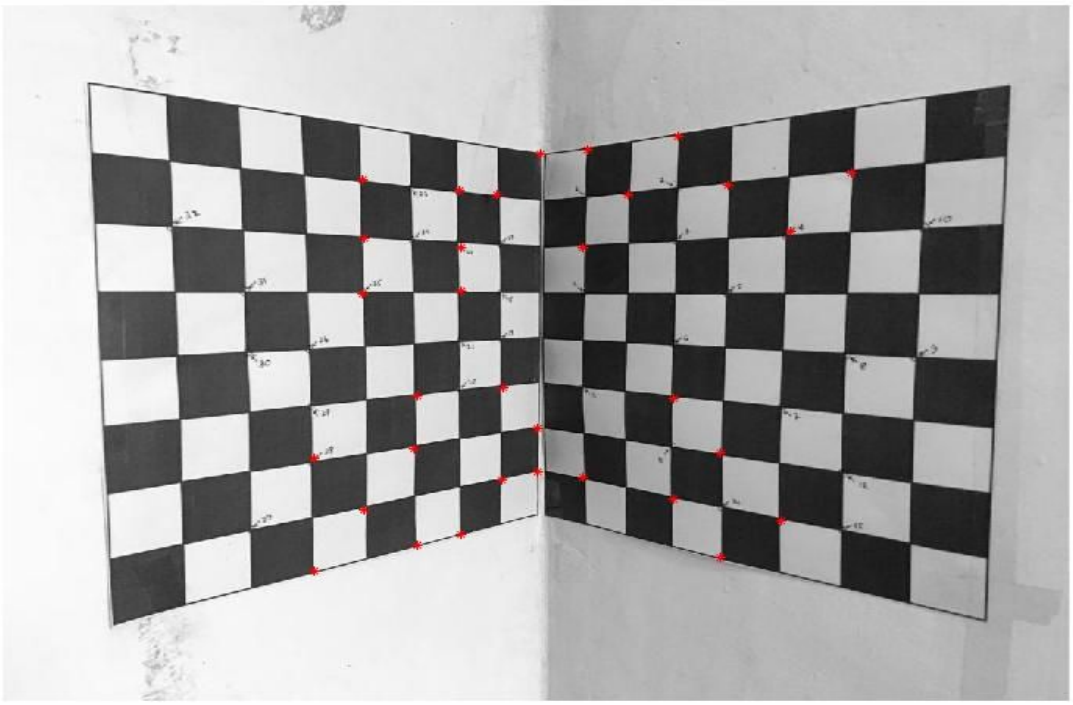
Indoor Scene Diagram :



Co-responding the gray level Diagram :



Indoor Selected Corner Points :



Intrinsic and Extrinsic Parameters obtained for Indoor Scene:

Indoor Scene

EXTRINSIC PARAMETERS

Rotation Matrix		
-0.7136378708	0.7004957696	-0.005163925913
-0.06320263698	-0.05704334065	0.9963691504
0.6976578072	0.7113731328	0.084981468

Translation Vector
-2.47E-05
-0.0002569903323
-0.001307336804

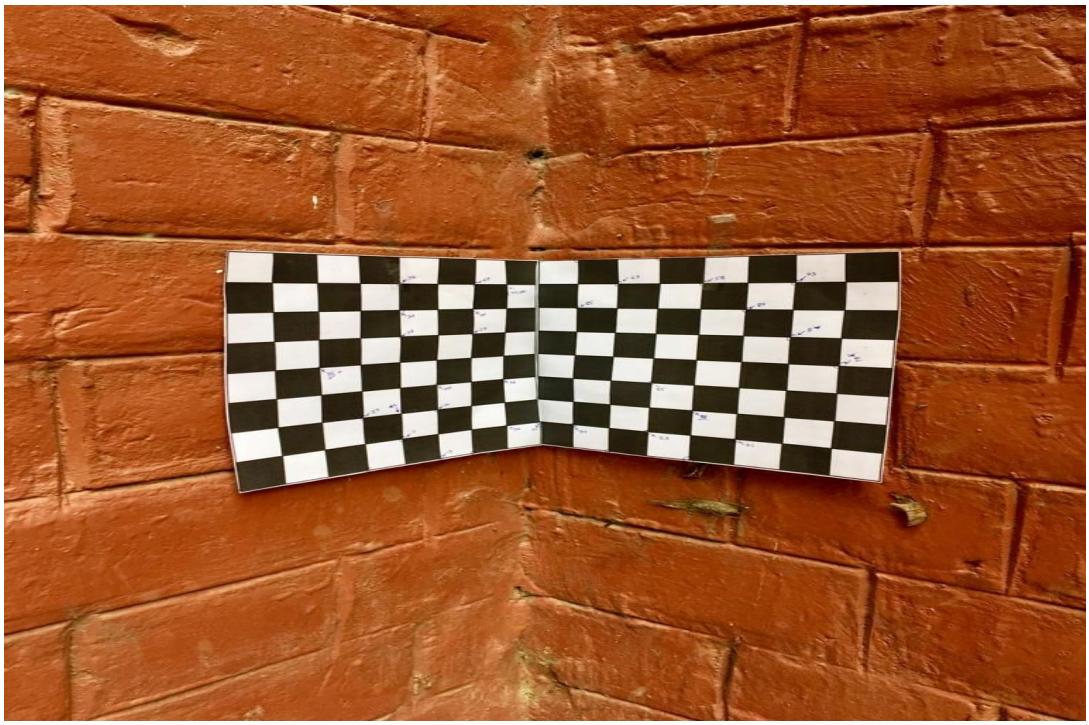
INTRINSIC PARAMETERS

K Matrix (Intrinsic Parameter Matrix.)		
898.4981563	3.073997804	498.5757302
0	871.57975	393.1715264
0	0	1

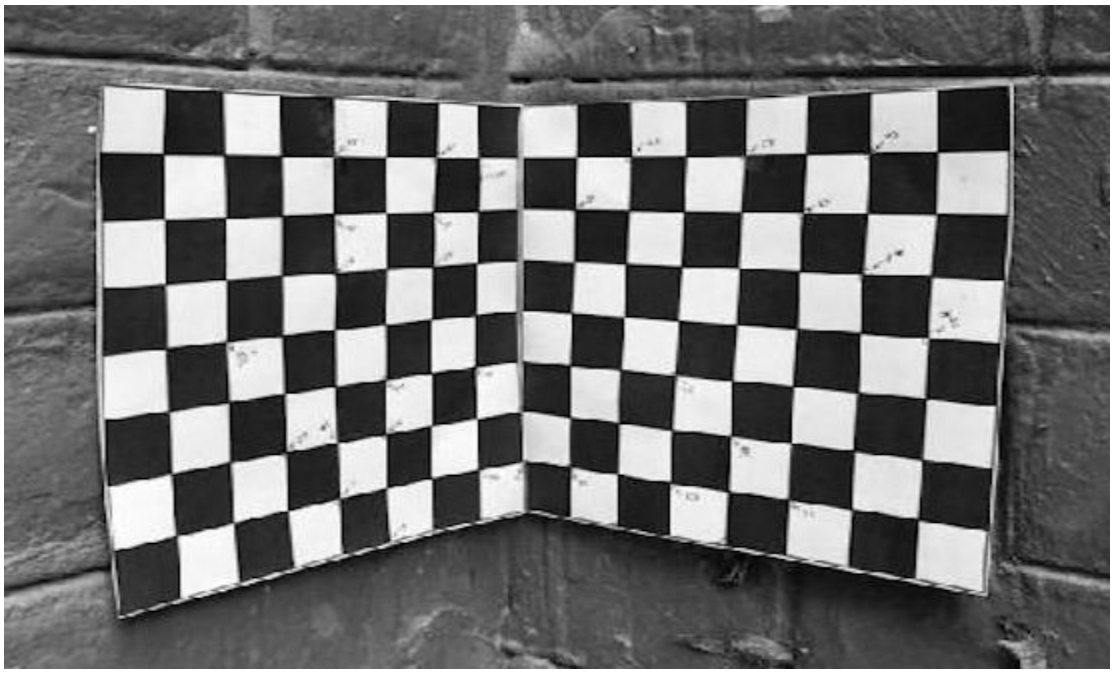
alpha	898.4982	x_0	498.5757302
beta	871.57	y_0	393.1715264
Theta	90.15 deg	Average Reprojection Error	2.0636

For the Outdoor Scene Scenario:

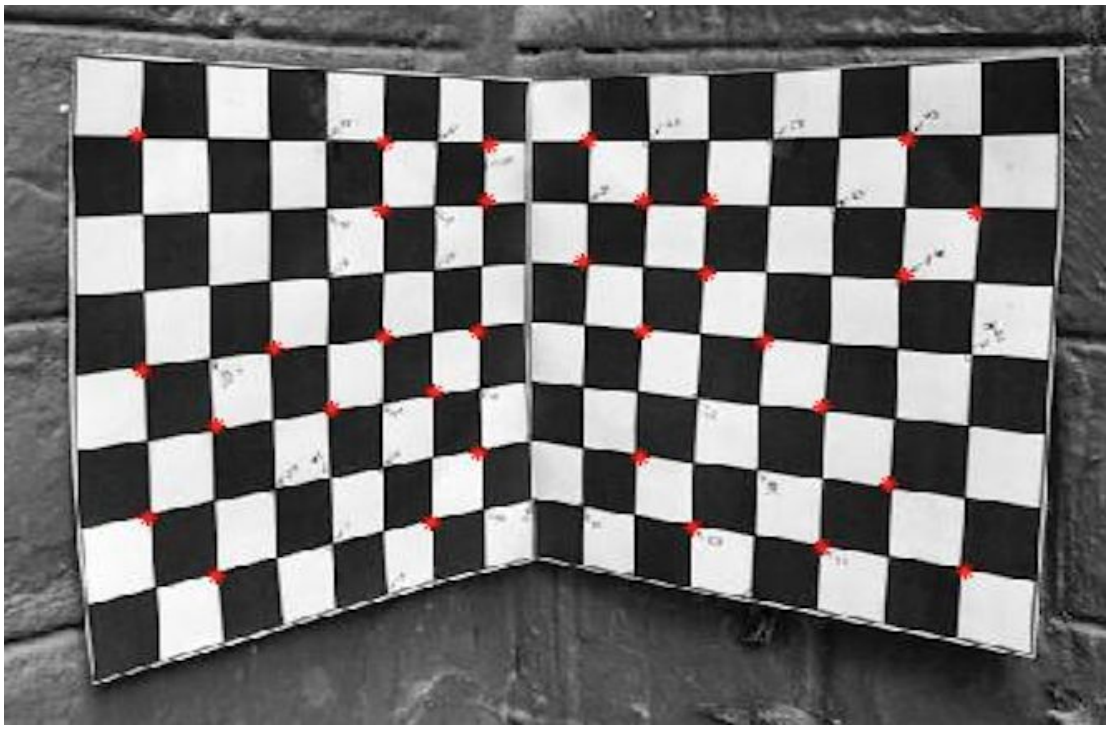
Outdoor Scene Diagram :



Outdoor Scene Gray Image :



Outdoor Scene Selected Points :



Intrinsic and Extrinsic Parameters obtained for Outdoor Scene:

Outdoor Scene

EXTRINSIC PARAMETERS

Rotation Matrix		
-0.7842533526	0.6204400051	0.0009375939077
-0.07181262333	-0.09227395527	0.9931407072
0.6162707409	0.7788065981	0.1169215832

Translation Vector
2.47E-05
-0.0001797408825
-0.001362531025

INTRINSIC PARAMETERS

K Matrix (Intrinsic Parameter Matrix.)		
895.4515852	-16.16244383	394.8515377
0	894.2484624	512.0200161
0	0	1

alpha	895.4516	**x_0**	394.8515377
beta	894.2485	**y_0**	512.0200161
Theta	88.93 deg	**Average Reprojection Error**	2.0915

Link of sheet which notes the dataValues:
https://docs.google.com/spreadsheets/d/1ZbogHVH7GfaBTavAP-yGPIUh95La4gVaesFul65hFHA/edit?usp=sharing

Observations made during the Assignment :

1. The corner algorithm has an effect on the brightness of the images as during the indoor corner point detection it was observed that the major corner points were detected in the brighter plane.
2. The Intrinsic and extrinsic parameter seems to be very close for both the indoor and outdoor scenes and theta was close to 90 degrees in both the cases.
3. The algorithm performance increases with the noted number of points .
4. All the sample points can not be on the same plane as it leads to degenerate case.
5. Testing Average reprojection error is low in both the cases around 2 units which ensure the correctness of the algorithm.