CV Assignment-2

Jaskaran Singh
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Ans 1

1)

```
Focal length (fx, fy): 1585.9978576532808, 1608.0433498341943
Skew parameter: 0.0
Principal point (cx, cy): 464.1850785281408, 384.67480518464845
Error estimates: 1.2935252540053748
Camera matrix: [[1.58599786e+03 0.00000000e+00 4.64185079e+02]
 [0.00000000e+00 1.60804335e+03 3.84674805e+02]
 [0.00000000e+00 0.00000000e+00 1.00000000e+00]]
```

2) Shown in Python notebook

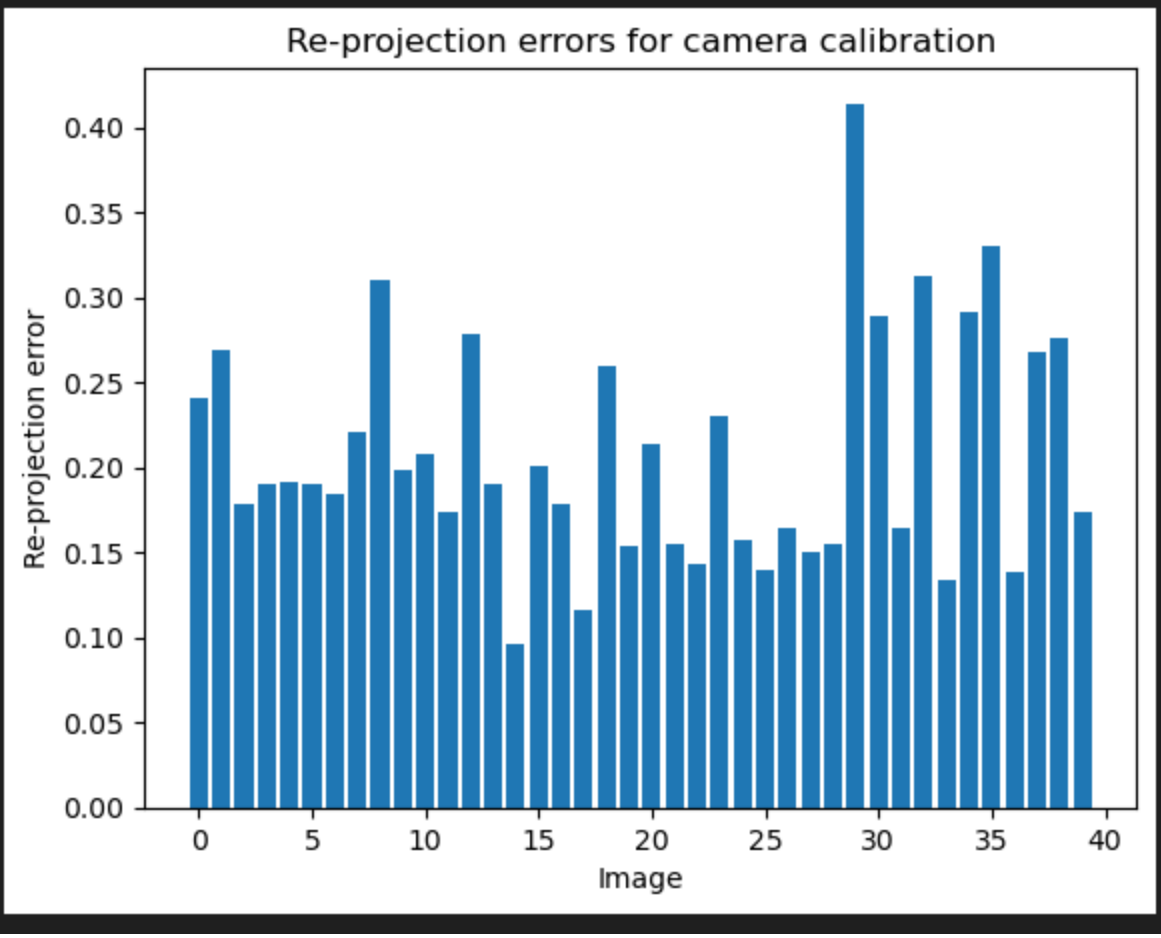
3)

```
Estimated radial distortion coefficients:
[[-0.52816138  2.55998753 -0.02144162 -0.01094063 -5.09133789]]
```

The straight lines at the corner of the images get curved because radial distortion causes an image to be stretched outwards from the center of the image, causing the straight lines to curve outwards. This effect is seen more in the corner of the images, where the distortion effect is stronger. The distortion is because of the circular lens of the camera.

4)

```
Mean re-projection error: 0.20818319038316221
Standard deviation of re-projection error: 0.06682610698001613
```



5) The re-projection error is computed as the Euclidean distance between the original image points and the re-projected image points.

6) Shown in Python notebook.

Ans 2

1) Shown in Python notebook.

2) The equations are as follows:
   Defining the variables,
   $\boldsymbol{\theta_c = [\theta_{c,1}\ \theta_{c,2}\ .\ .\ .\ \theta_{c,n}]^T,\ \ \theta_l = [\theta_{l,1}\ \theta_{l,2}\ .\ .\ .\ \theta_{l,n}]^T,}$
   $\boldsymbol{\alpha_c = [\alpha_{c,1}\ \alpha_{c,2}\ .\ .\ .\ \alpha_{c,n}]^T,\ \ \alpha_l = [\alpha_{l,1}\ \alpha_{l,2}\ .\ .\ .\ \alpha_{l,n}]^T}$
   Here,
   n is the number of image-lidar scan pairs,
   $\boldsymbol{\theta_c}$ is a 3xn vector representing the normal to the plane observed by the camera in the camera frame of reference,
   $\boldsymbol{\alpha_c}$ is a scalar representing the perpendicular distance from the origin to the plane observed by the camera in the camera frame of reference,
   $\boldsymbol{\theta_l}$ is a 3xn vector representing the normal to the plane observed by the laser in the laser frame of reference, and
   $\boldsymbol{\alpha_l}$ is a scalar representing the perpendicular distance from the origin to the plane observed by the laser in the laser frame of reference.

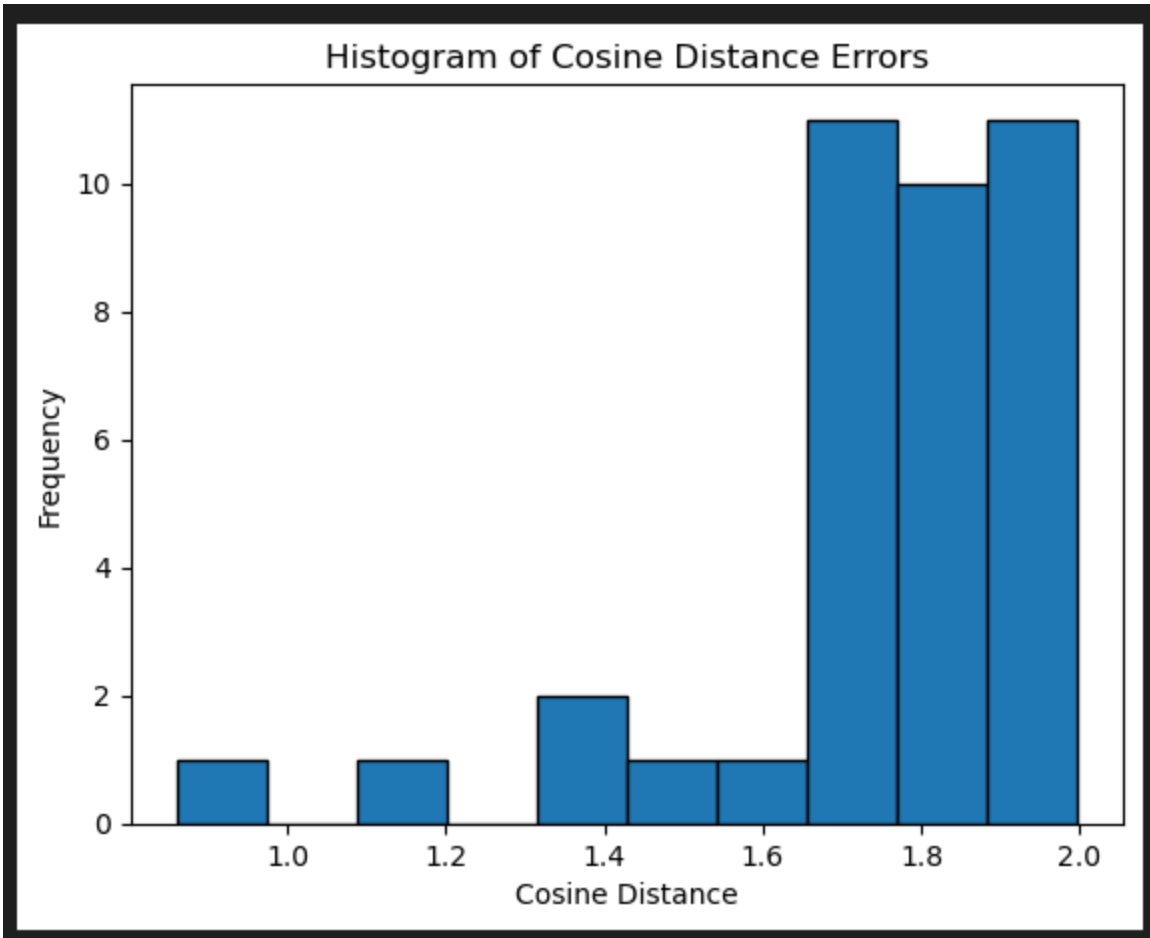
   $\boldsymbol{R = V\ U^T}$
   Here, **R** is the rotation matrix, and **V** and **U** are matrices obtained from the singular value decomposition of $\boldsymbol{\theta_l \theta_c^T}$.

   Euler-Rodrigues Equations:
   $\boldsymbol{S} = \theta_c^T \times \theta_l$
   $\boldsymbol{A} = [[0, -S_3, S_2], [S_3, 0, -S_1], [-S_2, S_1, 0]]$
   $\boldsymbol{R} = I + \sin(\theta) * A + (1 - \cos(\theta)) * A * A$

3) Shown in Python notebook.

4) Shown in Python notebook. No, the points are mostly not within the checkerboard pattern's boundary. However, all the points do lie in the image.

5)




```
Average error: 1.764549713674732
Standard deviation: 0.23775774942151728
```