ACTIVITY 1: Camera Calibration

Submitted by: Jonabel Eleanor B. Baldres

Applied Physics 167 THU

Main Objective

- *Model the physical processes involved in the geometric aspects of image formation*

Here, I used the equation: $a = (Q'Q)^{-1}Q'p$

where Q is the form given in equation (31), Q' is its corresponding transpose matrix, a is the matrix of camera parameters, and p are the image coordinates.

```
p = [1770;
    2628;
    2387;
    2716;
    2041;
    2300;
    2375;
    2312;
    2029;
    1932;
    2362;
    1908;
    1625;
    1798;
    1875;
    1595;
    2179;
    1543;
    2344;
    1317;
    1613;
    1312;
    2010;
    1200;
    1008;
    2884;
    843;
    2728;
    1414;
    2617;
    673;
    2561;
```

```
    1149;
    2491;
    1284;
    2301;
    840;
    2149;
    665;
    1748;
    1141;
    1783;
    1392;
    1478;
    832;
    1379;
    657;
    1144;
    1133;
    1251]
```

```
p = 50×1
        1770
        2628
        2387
        2716
        2041
        2300
        2375
        2312
        2029
        1932
    ⋮
```

```
Q = [0 2 1 1 0 0 0 0 -(1770*0) -(1770*2) -(1770*1);
    0 0 0 0 0 2 1 1 -(2628*0) -(2628*2) -(2628*1);

    0 6 1 1 0 0 0 0 -(2387*0) -(2387*6) -(2387*1);
    0 0 0 0 0 6 1 1 -(2716*0) -(2716*6) -(2716*1);

    0 4 3 1 0 0 0 0 -(2041*0) -(2041*4) -(2041*3);
    0 0 0 0 0 4 3 1 -(2300*0) -(2300*4) -(2300*3);

    0 6 3 1 0 0 0 0 -(2375*0) -(2375*6) -(2375*3);
    0 0 0 0 0 6 3 1 -(2312*0) -(2312*6) -(2312*3);

    0 4 5 1 0 0 0 0 -(2029*0) -(2029*4) -(2029*5);
    0 0 0 0 0 4 5 1 -(1932*0) -(1932*4) -(1932*5);

    0 6 5 1 0 0 0 0 -(2362*0) -(2362*6) -(2362*5);
    0 0 0 0 0 6 5 1 -(1908*0) -(1908*6) -(1908*5);

    0 1 6 1 0 0 0 0 -(1625*0) -(1625*1) -(1625*6);
```

```
0 0 0 0 0 1 6 1 -(1798*0) -(1798*1) -(1798*6);

0 3 7 1 0 0 0 0 -(1875*0) -(1875*3) -(1875*7);
0 0 0 0 0 3 7 1 -(1595*0) -(1595*3) -(1595*7);

0 5 7 1 0 0 0 0 -(2179*0) -(2179*5) -(2179*7);
0 0 0 0 0 5 7 1 -(1543*0) -(1543*5) -(1543*7);

0 6 8 1 0 0 0 0 -(2344*0) -(2344*6) -(2344*8);
0 0 0 0 0 6 8 1 -(1317*0) -(1317*6) -(1317*8);

0 1 9 1 0 0 0 0 -(1613*0) -(1613*1) -(1613*9);
0 0 0 0 0 1 9 1 -(1312*0) -(1312*1) -(1312*9);

0 4 9 1 0 0 0 0 -(2010*0) -(2010*4) -(2010*9);
0 0 0 0 0 4 9 1 -(1200*0) -(1200*4) -(1200*9);

4 0 0 1 0 0 0 0 -(1008*4) -(1008*0) -(1008*0);
0 0 0 0 4 0 0 1 -(2884*4) -(2884*0) -(2884*0);

5 0 1 1 0 0 0 0 -(843*5) -(843*0) -(843*1);
0 0 0 0 5 0 1 1 -(2728*5) -(2728*0) -(2728*1);

1 0 1 1 0 0 0 0 -(1414*1) -(1414*0) -(1414*1);
0 0 0 0 1 0 1 1 -(2617*1) -(2617*0) -(2617*1);

6 0 2 1 0 0 0 0 -(673*6) -(673*0) -(673*2);
0 0 0 0 6 0 2 1 -(2561*6) -(2561*0) -(2561*2);

3 0 2 1 0 0 0 0 -(1149*3) -(1149*0) -(1149*2);
0 0 0 0 3 0 2 1 -(2491*3) -(2491*0) -(2491*2);

2 0 3 1 0 0 0 0 -(1284*2) -(1284*0) -(1284*3);
0 0 0 0 2 0 3 1 -(2301*2) -(2301*0) -(2301*3);

5 0 4 1 0 0 0 0 -(840*5) -(840*0) -(840*4);
0 0 0 0 5 0 4 1 -(2149*5) -(2149*0) -(2149*4);

6 0 6 1 0 0 0 0 -(665*6) -(665*0) -(665*6);
0 0 0 0 6 0 6 1 -(1748*6) -(1748*0) -(1748*6);

3 0 6 1 0 0 0 0 -(1141*3) -(1141*0) -(1141*6);
0 0 0 0 3 0 6 1 -(1783*3) -(1783*0) -(1783*6);

1 0 8 1 0 0 0 0 -(1392*1) -(1392*0) -(1392*8);
0 0 0 0 1 0 8 1 -(1478*1) -(1478*0) -(1478*8);

5 0 8 1 0 0 0 0 -(832*5) -(832*0) -(832*8);
0 0 0 0 5 0 8 1 -(1379*5) -(1379*0) -(1379*8);
```

```
    6 0 9 1 0 0 0 0 -(657*6) -(657*0) -(657*9);
    0 0 0 0 6 0 9 1 -(1144*6) -(1144*0) -(1144*9);

    3 0 9 1 0 0 0 0 -(1133*3) -(1133*0) -(1133*9);
    0 0 0 0 3 0 9 1 -(1251*3) -(1251*0) -(1251*9)]
```

```
Q = 50×11
     0     2     1     1     0     0 ···
     0     0     0     0     0     2
     0     6     1     1     0     0
     0     0     0     0     0     6
     0     4     3     1     0     0
     0     0     0     0     0     4
     0     6     3     1     0     0
     0     0     0     0     0     6
     0     4     5     1     0     0
     0     0     0     0     0     4
   ⋮
```

```
a = pinv(Q'*Q)*Q'*p
```

```
a = 11×1
10^3 ×
   -0.1681
    0.0562
   -0.0006
    1.5291
   -0.0770
   -0.0790
   -0.1545
    2.7542
   -0.0000
   -0.0000
     ⋮
```

Testing the obtained camera parameters

Here, I predict the image coordinates of some points of the checkboard which were not used in the calibration. I then use the equations below to calculate the x_i and y_i image coordinates.

$$x_i = \frac{a_{11}x_0 + a_{12}y_0 + a_{13}z_0 + a_{14}}{a_{31}x_0 + a_{32}y_0 + a_{33}z_0 + a_{34}}$$

$$y_i = \frac{a_{21}x_0 + a_{22}y_0 + a_{23}z_0 + a_{24}}{a_{31}x_0 + a_{32}y_0 + a_{33}z_0 + a_{34}}$$

```
point_1 = [0 5 1];
point_2 = [0 2 3];
point_3 = [3 0 9];
point_4 = [3 0 5];
point_5 = [6 0 3];
```

```
[point_1_x, point_1_y] = Image(point_1, a)
```

```
point_1_x = 2.2100e+03
point_1_y = 2.6923e+03
```

```
[point_2_x, point_2_y] = Image(point_2, a)
```

```
point_2_x = 1.7596e+03
point_2_y = 2.2883e+03
```

```
[point_3_x, point_3_y] = Image(point_3, a)
```

```
point_3_x = 1.1320e+03
point_3_y = 1.2570e+03
```

```
[point_4_x, point_4_y] = Image(point_4, a)
```

```
point_4_x = 1.1431e+03
point_4_y = 1.9578e+03
```

```
[point_5_x, point_5_y] = Image(point_5, a)
```

```
point_5_x = 668.5605
point_5_y = 2.3552e+03
```

```
function [x, y] = Image(c, a)
    x = (a(1) * c(1) + a(2) * c(2) + a(3) * c(3) + a(4)) / (a(9) * c(1) +
a(10) * c(2) + a(11) * c(3) + 1);
    y = (a(5) * c(1) + a(6) * c(2) + a(7) * c(3) + a(8)) / (a(9) * c(1) +
a(10) * c(2) + a(11) * c(3) + 1);
end
```