Intro to Computer Vision
Lab-6

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Contents

1 Introduction

Camera Calibration Often in camera that captures the images has some distortion due to the lens and materials used in it. These distortions can be corrected using camera calibration in which we estimate the lens and camera distortions to correct the coordinates to obtain the image or the objects real world coordinates with respect to the camera. There are various methods to obtain this camera calibration parameters in this experiment we use the Tsai camera model and clibration technique to measure the parameters of the camera calibration to obtain the world coordinates of the objects in the experiment and then track them in our tracking area. For this we use two sofwtares deveoped by Dr. Hoover and his team. The two sofwtares that we used for this experiment is Calibration.exe and OccMap.exe, where Calibration.exe was used for calibration and OccMap.exe was used to check my caibration. The steps that I followed to calibrate and test is mentioned in the following section.

2 Method and Results

For this I used the camera network in the Riggs 13/15/17 lab. I followed the below steps to do the experiment to caibration of the camera.

Calibration steps: In the lab computer I used the Calibration.exe software to do this experiment.

1. First I took 6 calibration targets and spread it on the floor to make a grid. I took a target with a cross made on it instead of a square to identify it as a marker for my chosen origin(0,0) in the world coordinates.I also decided my X-axis and Y-axis in the grid to map it in the calibration software. I took the small axis from my orgin as x-axis and the long axis as Y-axis. Below are my calibrate images that I took. The calbration.exe recognized my grid as a 4x6 matrix and then asked few questions to make sure of the coordinates that it recognized and also the direction of x-axis and y-axis.Below are the images and the coordinates that it recognised in my case.:

Figure 1: Cam 0, the shorter side is X-Axis and the longer side is Y-axis

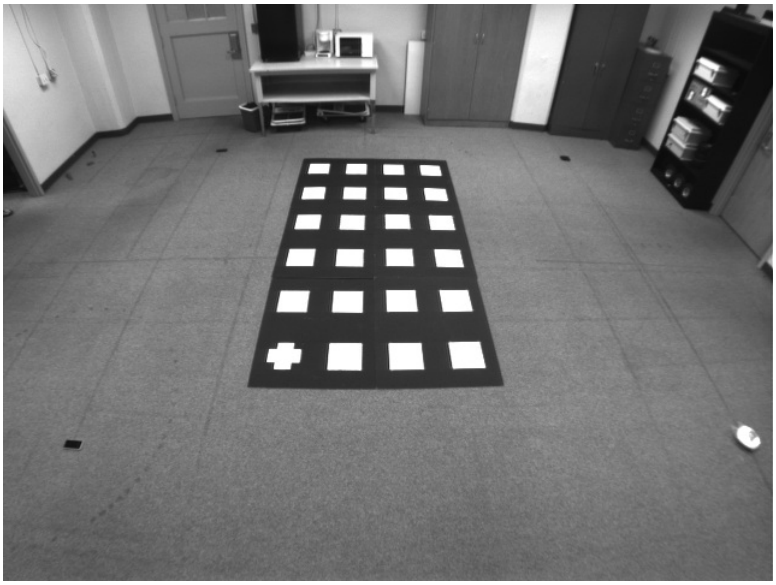

Figure 2: Cam 1

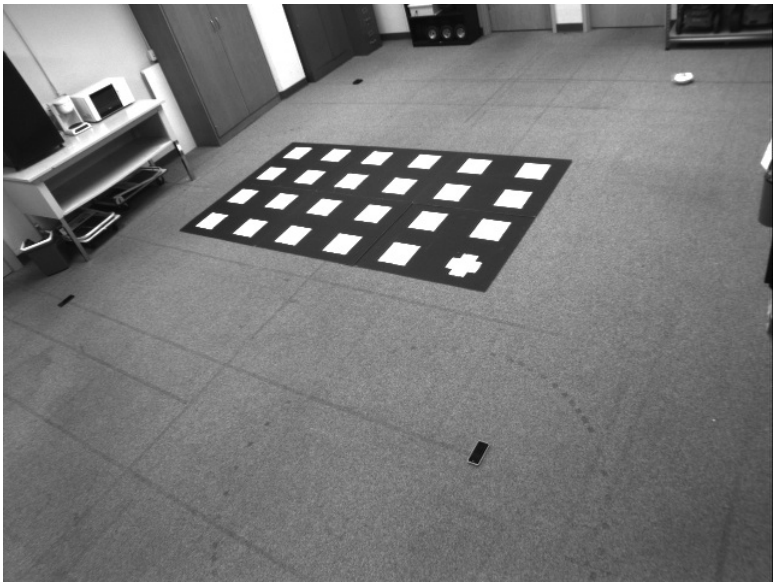

Figure 3: Cam 2

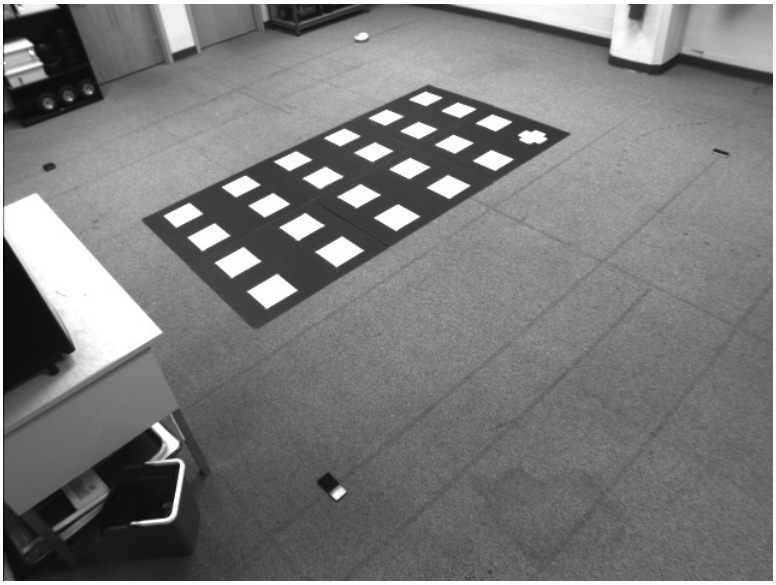

Figure 4: Cam 3

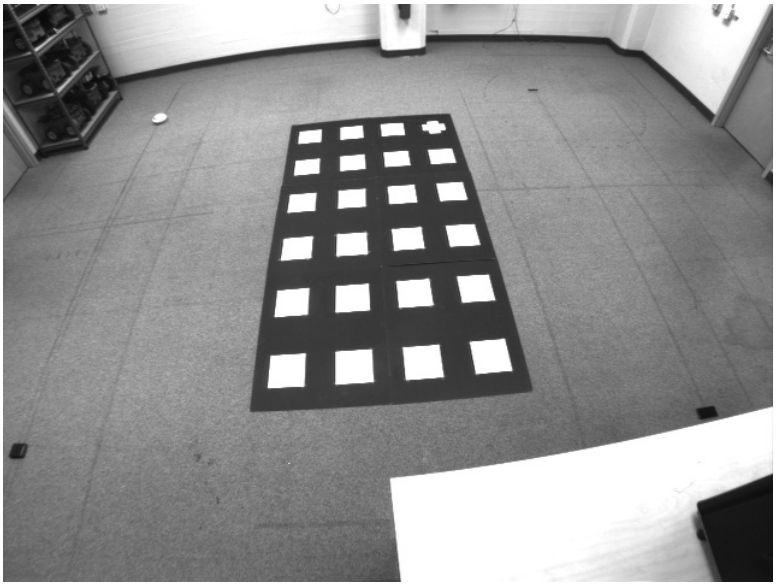

Figure 5: Cam 4

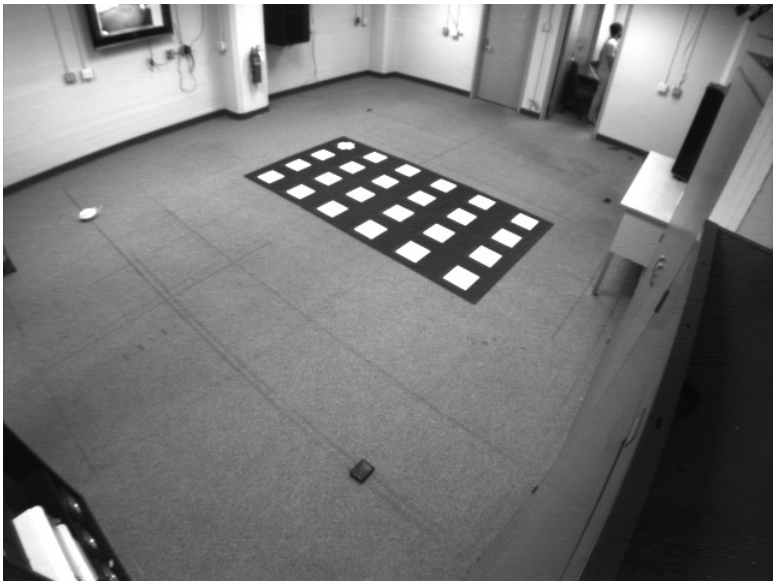

Figure 6: Cam 5

Using the above images I got the coordinates which are shown in the table mentioned below. The screenshot for the cam 0 is displayed below.

Cam	X	Y	Z
0	3889	-1197	2333
1	593	-1736	2270
2	-2181	-1484	2022
3	-2553	3721	2316
4	586	3784	2282
5	3753	3712	2280

Image or screenshot of the coordinates that I got from cam-0.

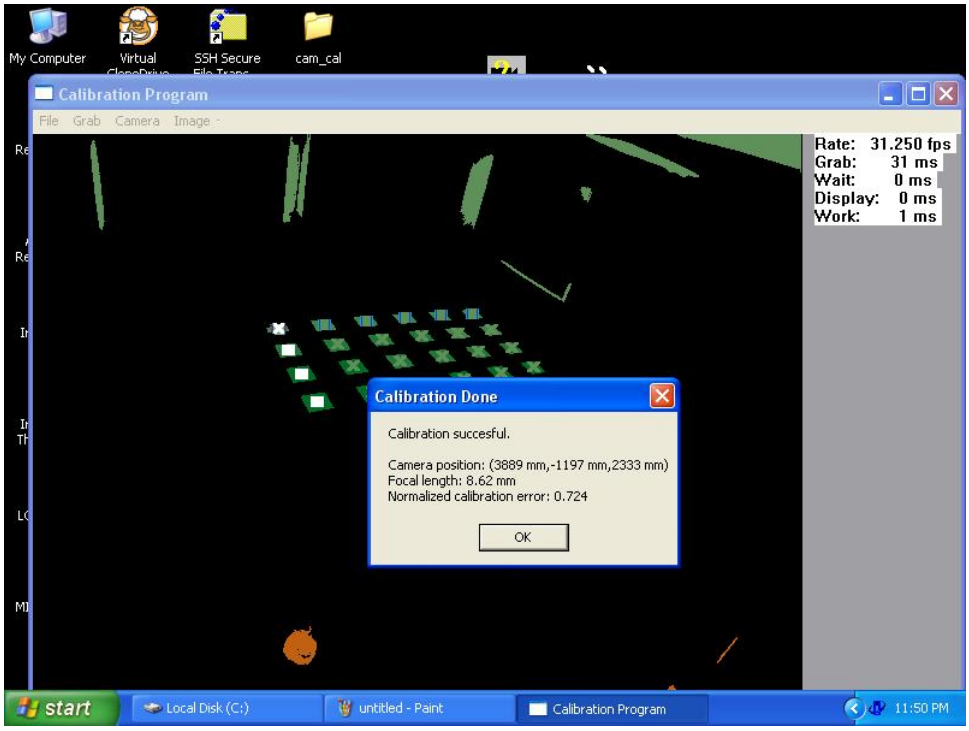

Figure 7: screenshot of the coordinates that I obtain. This is only for the cam0. I got similar screenshots for all the rest of the 5 cameras.

2. After calibration of the coordinates, I removed the grids spread on the floor to capture the background image which will be used for the tracking of our object in the rectangular area. As shown in the image following we placed four objects at the corners of our imaginary boundary of the tracking area to keep track of the area which should be calibrated for the tracking area. In the process we took a snapshot from the camera and draw my cotours around the imaginary backgrund area of tracking, below are the 6 background images that we captured and also the corresponding floor.txt files which shows our points to snap the background image of the floor.

Figure 8: screenshot of the coordinates that I obtain. This is only for the cam0. I got similar screenshots for all the rest of the 5 cameras.

Contents from the file $Floor_0.txt$ which represents the points that I captured for drawing the contours.

132 122 349 114 404 160 465 212 537 273 459 319 355 370 224 428 190 326 149 190 132

Figure 9: Cam 1

Contents from the file $Floor_1.txt$ which represents the points that I captured for drawing the contours.

56 364 111 249 153 167 180 121 285 118 378 122 468 128 511 184 556 255 618 356 466

Figure 10: Cam 2

Contents from the file $Floor_2.txt$ which represents the points that I captured for drawing the contours.

52 244 184 299 394 375 463 257 526 141 565 61 423 59 295 61 237 102 146 171 52 244

Figure 11: Cam 3

Contents from the file $Floor_3.txt$ which represents the points that I captured for drawing the contours.

37 132 299 27 414 67 601 123 498 215 400 301 273 403 177 305 92 203 37 132

Figure 12: Cam 4

Contents from the file $Floor_4.txt$ which represents the points that I captured for drawing the contours.

10 369 54 251 107 138 129 95 246 79 365 69 440 69 494 152 540 240 586 337 426 354 18

Figure 13: Cam 5

Contents from the file $Floor_5.txt$ which represents the points that I captured for drawing the contours.

68 173 129 240 200 310 296 391 409 274 462 213 504 163 424 130 348 102 305 88 244 10

3. After the calibration and background images were recognized. All the data was used to test my tracking. I opened the OccMap.exe application and I found a rectangular area for tracking and then used a chair in the lab to push into the tracking area and I successfully found it with no shadows in it proving that the images or camera feed all the cameras are considered and is displayed.

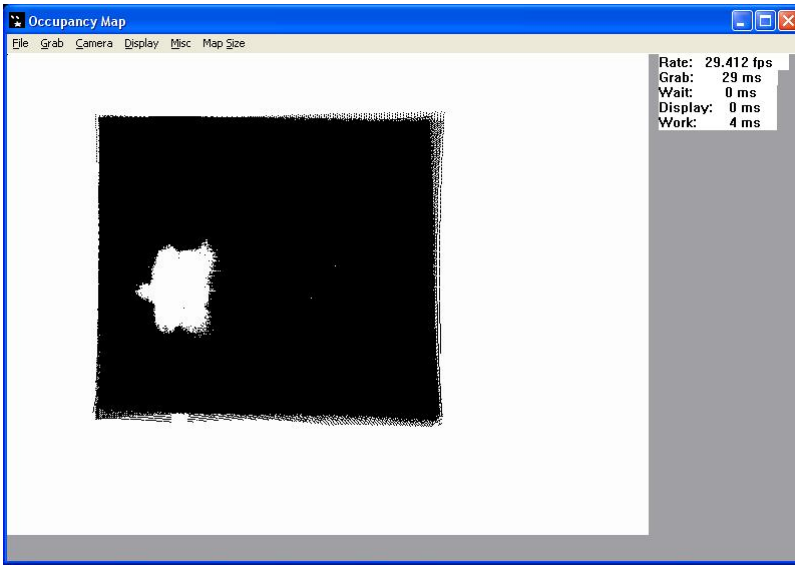

Figure 14: Final Result. Chair blob is obtained in my tracking area.

3 Conclusion

In the Lab I learnt the techniques on how to use a check grid system to do the camera calibration.I also learnt how to check if my camera calibration is showing correct result or not.

4 Appendix

Listing 1: $Calib_0.txt$

```
 6.4000000000e+002
 6.4000000000e+002
 2.3000000000e-002
 2.3000000000e-002
 2.3000000000e-002
 2.3000000000e-002
 3.2171928043e+002
 2.1994312352e+002
 1.0000000000e+000
 8.6180066700e+000
 5.0156408707e-003
-1.4588349731e+003
-7.1304083974e+002
 4.3999772266e+003
 2.4075708797e+000
 6.6934479108e-001
 8.8240613744e-001
 0.0000000000e+000
 0.0000000000e+000
```

Listing 2: $Calib_1.txt$

```
 6.4000000000e+002
 6.4000000000e+002
 2.3000000000e-002
 2.3000000000e-002
 2.3000000000e-002
 2.3000000000e-002
 3.3891890684e+002
 2.6099984210e+002
 1.0000000000e+000
 8.2409721620e+000
 3.8330626268e-003
-8.4244204491e+002
 2.5181434891e+002
 2.7826825739e+003
 2.4014972949e+000
-8.8987307041e-002
-3.1212232523e-003
 0.0000000000e+000
 0.0000000000e+000
```

Listing 3: $Calib_2.txt$

```
 6.4000000000e+002
 6.4000000000e+002
 2.3000000000e-002
 2.3000000000e-002
 2.3000000000e-002
 2.3000000000e-002
 3.7006552314e+002
 2.7362709257e+002
 1.0000000000e+000
 9.7553835125e+000
 9.5147408679e-004
 9.6928713781e+001
```

```
−4.4060011865e+002
 3.2925525707e+003
 2.5743487027e+000
−5.8994743005e−001
−9.8026664860e−001
 0.0000000000e+000
 0.0000000000e+000
```

Listing 4: $Calib_3.txt$

```
 6.4000000000e+002
 6.4000000000e+002
 2.3000000000e−002
 2.3000000000e−002
 2.3000000000e−002
 2.3000000000e−002
 2.9856680118e+002
 1.8145639175e+002
 1.0000000000e+000
 1.1643683401e+001
 1.9656050283e−003
 1.3819288760e+003
−6.9854525235e+002
 4.8303589153e+003
−2.4291217654e+000
−7.1970827969e−001
−2.6111916490e+000
 0.0000000000e+000
 0.0000000000e+000
```

Listing 5: $Calib_4.txt$

```
 6.4000000000e+002
 6.4000000000e+002
 2.3000000000e−002
 2.3000000000e−002
 2.3000000000e−002
 2.3000000000e−002
 3.1516698310e+002
 2.3113617653e+002
 1.0000000000e+000
 8.4013167128e+000
 3.8684361564e−003
 5.0469302671e+002
−1.5277331573e+003
 4.1569526301e+003
−2.4561061950e+000
−8.0457594628e−003
 3.0652915512e+000
 0.0000000000e+000
 0.0000000000e+000
```

Listing 6: $Calib_5.txt$

```
 6.4000000000e+002
 6.4000000000e+002
 2.3000000000e-002
 2.3000000000e-002
 2.3000000000e-002
 2.3000000000e-002
 3.0661966350e+002
 2.3191343344e+002
 1.0000000000e+000
 8.1656425129e+000
 2.8553635841e-003
-3.4323229661e+002
-1.7985415391e+003
 5.4509219285e+003
-2.5127008060e+000
 6.0972603439e-001
 2.5184458530e+000
 0.0000000000e+000
 0.0000000000e+000
```

Listing 7: $CalPoints_0.txt$

```
0.000000  0.000000  0.000000  203.245902  161.909836
0.000000  508.000000  0.000000  241.184932  158.424658
0.000000  1016.000000  0.000000  276.542636  155.271318
0.000000  1524.000000  0.000000  308.870690  152.905172
0.000000  2032.000000  0.000000  338.031915  150.872340
0.000000  2540.000000  0.000000  364.690476  149.261905
406.000000  0.000000  0.000000  211.989950  179.306533
406.000000  508.000000  0.000000  252.353933  174.808989
406.000000  1016.000000  0.000000  289.168831  170.675325
406.000000  1524.000000  0.000000  322.796992  167.691729
406.000000  2032.000000  0.000000  352.844828  165.025862
406.000000  2540.000000  0.000000  380.387755  162.795918
812.000000  0.000000  0.000000  222.564516  199.153226
812.000000  508.000000  0.000000  265.871560  192.986239
812.000000  1016.000000  0.000000  304.567568  188.335135
812.000000  1524.000000  0.000000  339.753165  184.183544
812.000000  2032.000000  0.000000  369.953846  180.553846
812.000000  2540.000000  0.000000  397.110092  177.477064
1218.000000  0.000000  0.000000  235.824675  222.474026
1218.000000  508.000000  0.000000  281.465649  214.610687
1218.000000  1016.000000  0.000000  321.417040  208.636771
1218.000000  1524.000000  0.000000  357.705263  203.000000
1218.000000  2032.000000  0.000000  388.103226  198.051613
1218.000000  2540.000000  0.000000  415.483871  193.612903
```

Listing 8: $CalPoints_1.txt$

```
0.000000  0.000000  0.000000  233.137387  292.423423
0.000000  508.000000  0.000000  240.818182  247.031941
0.000000  1016.000000  0.000000  247.135762  210.543046
0.000000  1524.000000  0.000000  253.246637  180.856502
0.000000  2032.000000  0.000000  258.023952  156.904192
0.000000  2540.000000  0.000000  262.238462  136.561538
406.000000  0.000000  0.000000  283.866776  292.710526
406.000000  508.000000  0.000000  286.406542  247.336449
406.000000  1016.000000  0.000000  287.710526  210.555921
```

```
406.000000 1524.000000 0.000000 290.022523 181.306306
406.000000 2032.000000 0.000000 291.890909 156.981818
406.000000 2540.000000 0.000000 293.305344 136.557252
812.000000 0.000000 0.000000 334.437811 292.577114
812.000000 508.000000 0.000000 330.728311 246.591324
812.000000 1016.000000 0.000000 329.254125 210.557756
812.000000 1524.000000 0.000000 327.420168 180.542017
812.000000 2032.000000 0.000000 325.948571 157.337143
812.000000 2540.000000 0.000000 324.119403 137.455224
1218.000000 0.000000 0.000000 385.088696 291.699130
1218.000000 508.000000 0.000000 375.740566 246.450472
1218.000000 1016.000000 0.000000 369.948387 211.177419
1218.000000 1524.000000 0.000000 364.055794 181.575107
1218.000000 2032.000000 0.000000 359.127907 158.023256
1218.000000 2540.000000 0.000000 354.856061 138.098485
```

Listing 9: $CalPoints_2.txt$

```
0.000000 2540.000000 0.000000 172.944751 179.674033
406.000000 2540.000000 0.000000 198.878049 159.250000
812.000000 2540.000000 0.000000 222.680556 140.395833
1218.000000 2540.000000 0.000000 244.446154 123.207692
0.000000 2032.000000 0.000000 205.054299 185.416290
406.000000 2032.000000 0.000000 230.933673 163.326531
812.000000 2032.000000 0.000000 254.442529 143.201149
1218.000000 2032.000000 0.000000 276.178808 125.211921
0.000000 1524.000000 0.000000 240.661818 191.570909
406.000000 1524.000000 0.000000 266.495726 168.260684
812.000000 1524.000000 0.000000 288.950980 146.617647
1218.000000 1524.000000 0.000000 310.453039 127.569061
0.000000 1016.000000 0.000000 281.773585 198.779874
406.000000 1016.000000 0.000000 307.032258 173.727599
812.000000 1016.000000 0.000000 328.890295 150.679325
1218.000000 1016.000000 0.000000 349.617647 130.450980
0.000000 508.000000 0.000000 328.888041 206.956743
406.000000 508.000000 0.000000 352.813456 179.749235
812.000000 508.000000 0.000000 372.752650 155.975265
1218.000000 508.000000 0.000000 391.561181 134.371308
0.000000 0.000000 0.000000 382.450000 216.486111
406.000000 0.000000 0.000000 404.526582 187.055696
812.000000 0.000000 0.000000 423.538226 161.388379
1218.000000 0.000000 0.000000 439.959707 138.285714
```

Listing 10: $CalPoints_3.txt$

```
1218.000000 2540.000000 0.000000 149.202454 175.168712
1218.000000 2032.000000 0.000000 197.276978 151.100719
1218.000000 1524.000000 0.000000 240.539683 130.126984
1218.000000 1016.000000 0.000000 281.477064 110.435780
1218.000000 508.000000 0.000000 317.753927 93.979058
1218.000000 0.000000 0.000000 350.769697 78.327273
812.000000 2540.000000 0.000000 170.515228 193.261421
812.000000 2032.000000 0.000000 220.817910 166.883582
812.000000 1524.000000 0.000000 265.336667 143.980000
812.000000 1016.000000 0.000000 307.501931 122.783784
812.000000 508.000000 0.000000 345.133641 104.705069
812.000000 0.000000 0.000000 378.441489 87.808511
406.000000 2540.000000 0.000000 194.706861 214.484407
406.000000 2032.000000 0.000000 247.858852 184.913876
406.000000 1524.000000 0.000000 295.296830 159.253602
```

```
406.000000 1016.000000 0.000000 337.486486 136.304054
406.000000 508.000000 0.000000 374.600000 116.056000
406.000000 0.000000 0.000000 407.745283 98.306604
0.000000 2540.000000 0.000000 223.204013 238.463211
0.000000 2032.000000 0.000000 279.199605 205.452569
0.000000 1524.000000 0.000000 326.971360 177.035800
0.000000 1016.000000 0.000000 369.940510 151.634561
0.000000 508.000000 0.000000 406.989547 129.515679
0.000000 0.000000 0.000000 439.770492 110.267760
```

Listing 11: $CalPoints_4.txt$

```
1218.000000 2540.000000 0.000000 235.616060 304.430364
1218.000000 2032.000000 0.000000 239.865417 247.625213
1218.000000 1524.000000 0.000000 244.034247 202.579909
1218.000000 1016.000000 0.000000 248.210526 164.603715
1218.000000 508.000000 0.000000 252.364754 135.020492
1218.000000 0.000000 0.000000 254.983784 109.854054
812.000000 2540.000000 0.000000 291.554217 300.996386
812.000000 2032.000000 0.000000 290.250825 243.927393
812.000000 1524.000000 0.000000 289.648230 199.219027
812.000000 1016.000000 0.000000 289.450311 161.186335
812.000000 508.000000 0.000000 290.000000 131.414634
812.000000 0.000000 0.000000 289.576923 106.379121
406.000000 2540.000000 0.000000 348.580918 297.268116
406.000000 2032.000000 0.000000 341.594156 239.899351
406.000000 1524.000000 0.000000 336.018265 194.582192
406.000000 1016.000000 0.000000 331.378049 157.765244
406.000000 508.000000 0.000000 326.807377 128.163934
406.000000 0.000000 0.000000 323.454545 103.812834
0.000000 2540.000000 0.000000 404.978616 292.232704
0.000000 2032.000000 0.000000 392.450000 235.851724
0.000000 1524.000000 0.000000 381.549296 191.706573
0.000000 1016.000000 0.000000 372.586957 155.363354
0.000000 508.000000 0.000000 364.216102 126.008475
0.000000 0.000000 0.000000 357.609929 101.872340
```

Listing 12: $CalPoints_5.txt$

```
1218.000000 0.000000 0.000000 222.118110 143.228346
812.000000 0.000000 0.000000 244.843478 133.443478
406.000000 0.000000 0.000000 265.363636 125.000000
0.000000 0.000000 0.000000 284.594203 117.318841
1218.000000 508.000000 0.000000 246.883871 155.651613
812.000000 508.000000 0.000000 270.007463 144.813433
406.000000 508.000000 0.000000 289.826087 135.417391
0.000000 508.000000 0.000000 308.979592 127.112245
1218.000000 1016.000000 0.000000 273.284946 169.881720
812.000000 1016.000000 0.000000 296.776398 157.869565
406.000000 1016.000000 0.000000 317.367647 147.257353
0.000000 1016.000000 0.000000 335.982301 137.964602
1218.000000 1524.000000 0.000000 305.056522 186.913043
812.000000 1524.000000 0.000000 328.219895 173.371728
406.000000 1524.000000 0.000000 347.541401 161.082803
0.000000 1524.000000 0.000000 365.744186 150.604651
1218.000000 2032.000000 0.000000 340.177122 205.527675
812.000000 2032.000000 0.000000 361.981481 190.060185
406.000000 2032.000000 0.000000 380.847826 176.445652
0.000000 2032.000000 0.000000 397.682432 164.445946
1218.000000 2540.000000 0.000000 380.468750 227.212500
```

812.000000 2540.000000 0.000000 400.678295 209.406977
406.000000 2540.000000 0.000000 418.088235 194.088235
0.000000 2540.000000 0.000000 433.311377 180.538922