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
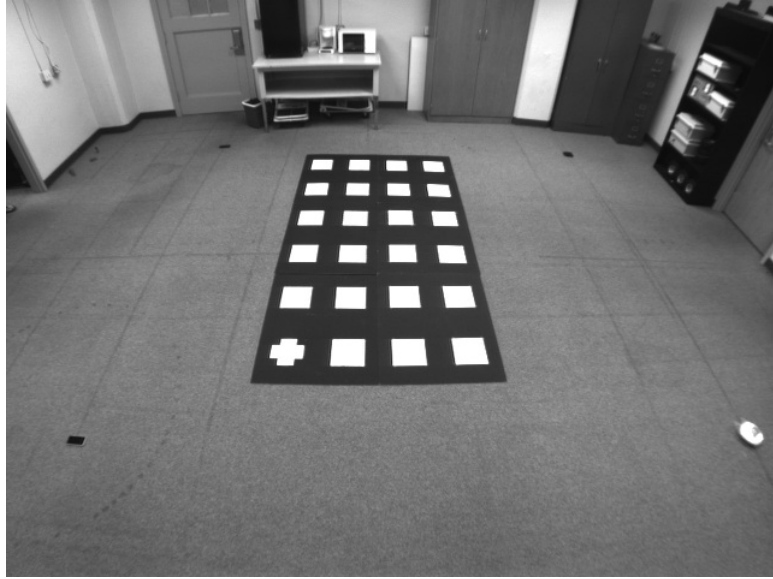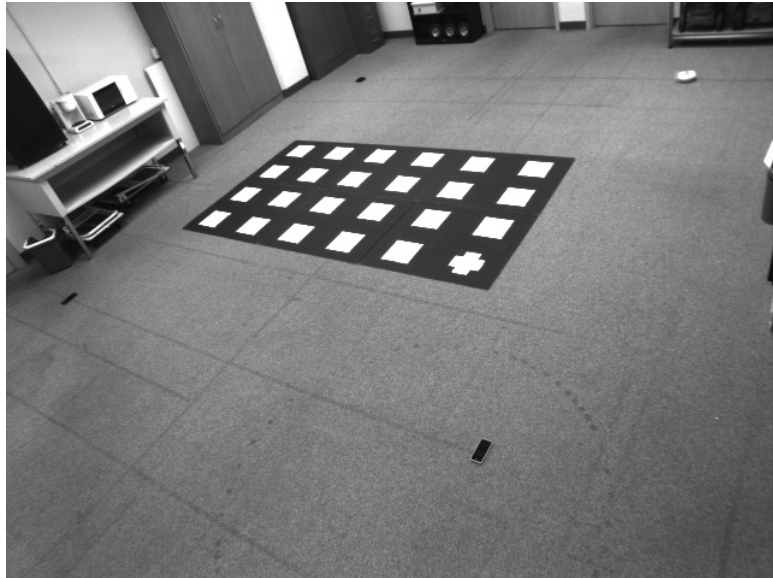
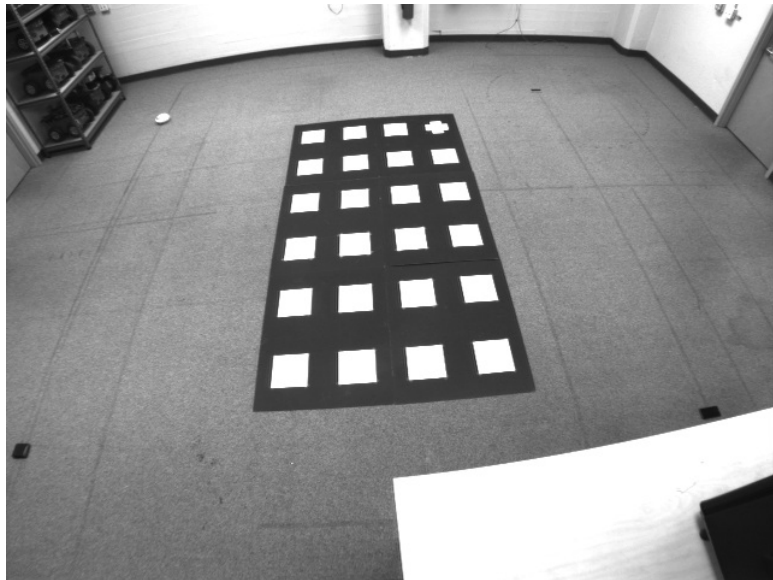Figure 2: Cam 1

Figure 3: Cam 2

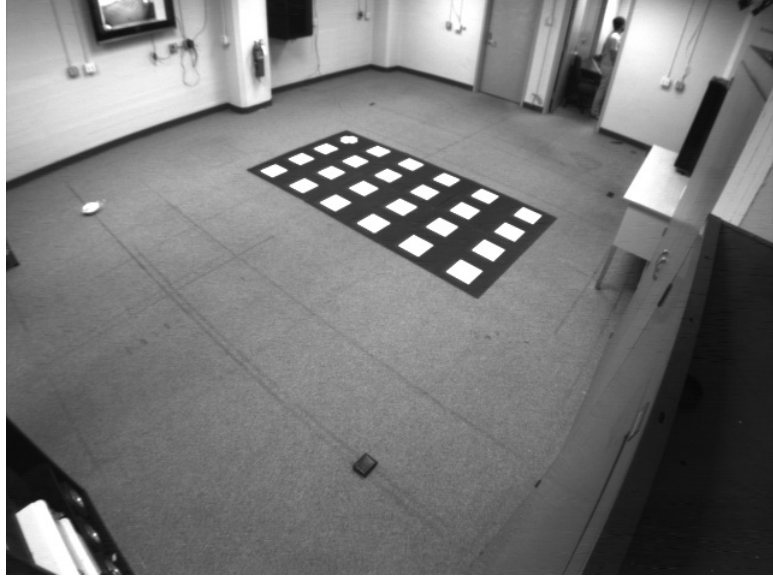Figure 4: Cam 3

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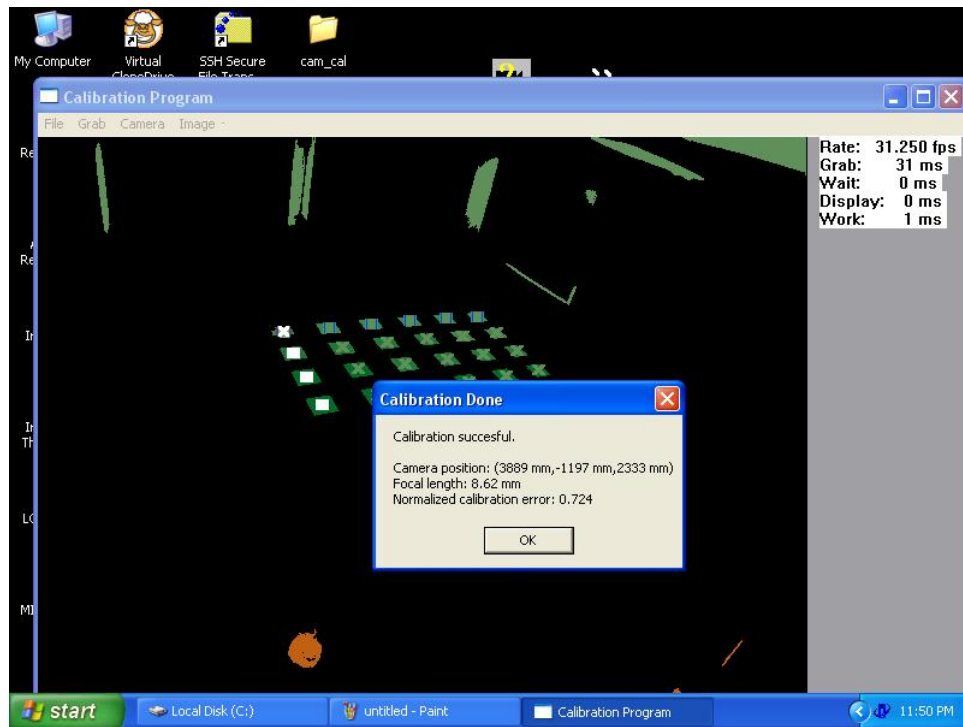
Figure 8: screenshot of the coordinates that I obtain. This is only for the cam0. I got similar screenshots for all the rest of the 5 cameras.

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 *Floor₂.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 *Floor₃.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.
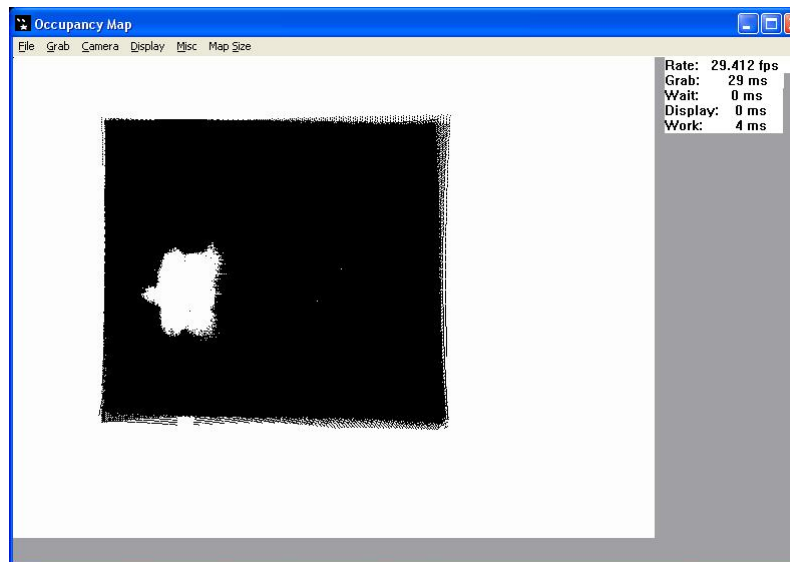
Figure 14: Final Result. Chair blob is obtained in my tracking area.

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: $Calib_0.txt$

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

Listing 2: $Calib_1.txt$

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

Listing 3: $Calib_2.txt$

```
  6.4000000000 e+002
  6.4000000000 e+002
  2.3000000000 e−002
  2.3000000000 e−002
  2.3000000000 e−002
  2.3000000000 e−002
  3.7006552314 e+002
  2.7362709257 e+002
  1.0000000000 e+000
  9.7553835125 e+000
  9.5147408679 e−004
  9.6928713781 e+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: $Calib_5.txt$

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