13-feb-2014
steps to compute camera calibration

1. obtain .zip file with matlab scripts and sample data files
(pba_sc.m, collin.m, gencof.m, gndx.m, int_leq2.m, cam.dat, cam_fix.dat,
cam_free.dat, cp.dat, delta.dat, pho.dat, phofiles.dat,sig.dat).
copy into a working folder.

2. copy your 8 measurement files (*****.txt) into the working folder.
each measurement file should have 9 x 3 = 27 lines with one point per line.

3. edit your 8 filenames into the file phofiles.dat (see sample later)
something like notepad works for this editing, do not make any formatting
as might be found in wordpad or MS word. the camera station name will be the file
name without the extension.

4. edit the position and attitude values in the file pho.dat (see sample later).
for the usual camera stations, the positions will be the same as the default values.
get the attitude data (omega, phi, kappa) from the angle table, depending on how
you held the camera (landscape, portrait, etc.). edit the photo station names
also into this file, pho.dat.

5. edit the file cam_fix.dat by editing your focal length in pixel units
into the proper field of the file.  copy this file into filename cam.dat
withing the working directory.

6. the file cp.dat describes the needed control points, no editing needed.

7. run the program pba_sc (photogrammetric bundle adjustment, self-calibration)
use the diary command to capture the screen output. observation RMS values
should be in the range 2 - 5 pixels. look through the residual listing, there should
be no outliers. if there are outliers, try reobserving those points and replacing
those observations. if it does not converge, check your initial approximations
for position and attitude of the camera stations.

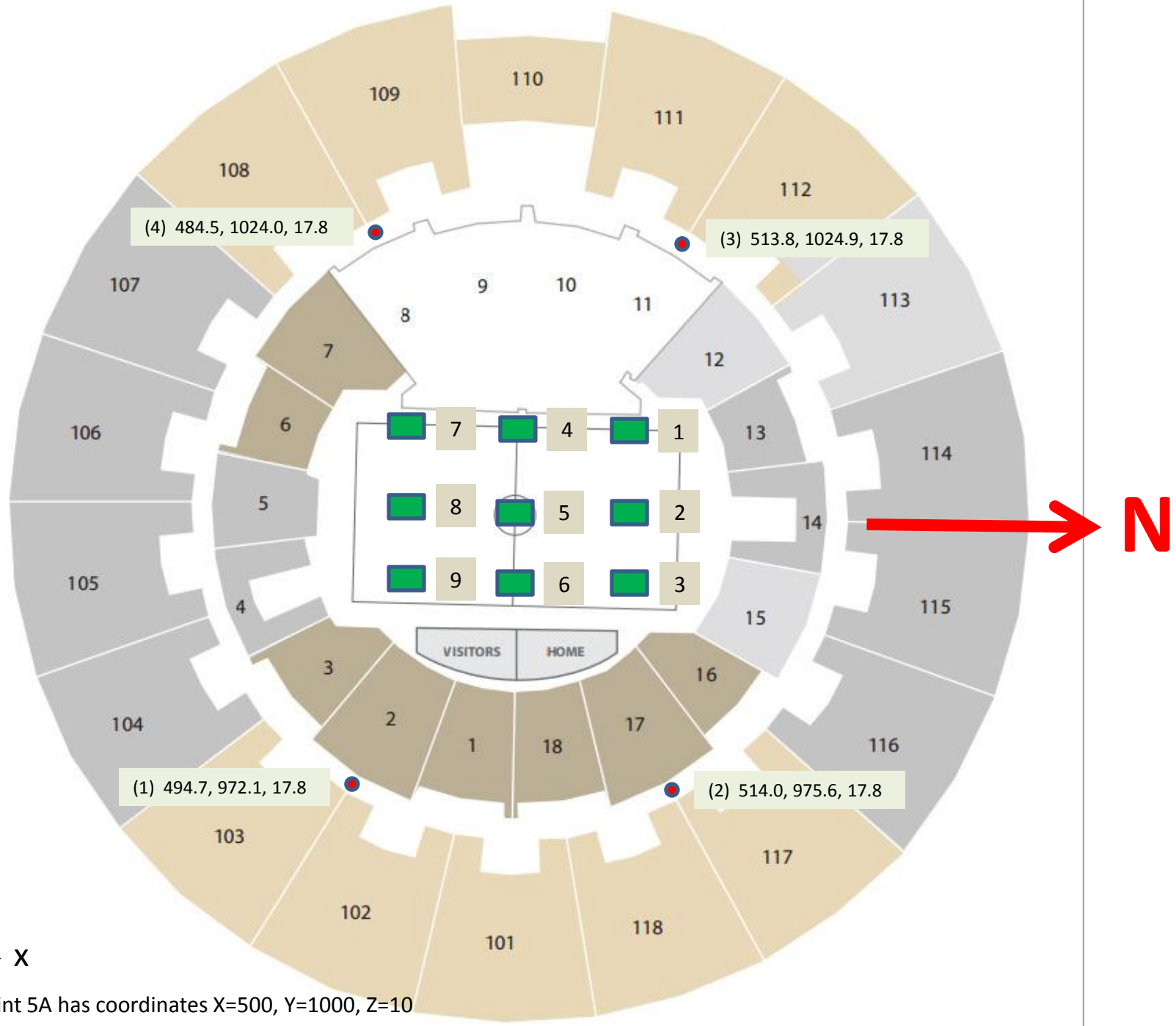
8. if results above are satisfactory, then edit your initial focal length
estimate into the file cam_free.dat. then copy that file into filename
cam.dat.

9 re-run the program pba_sc.  now your residuals should be much smaller,
RMS ~ 0.1 or 0.2 pixels, again with no outliers.

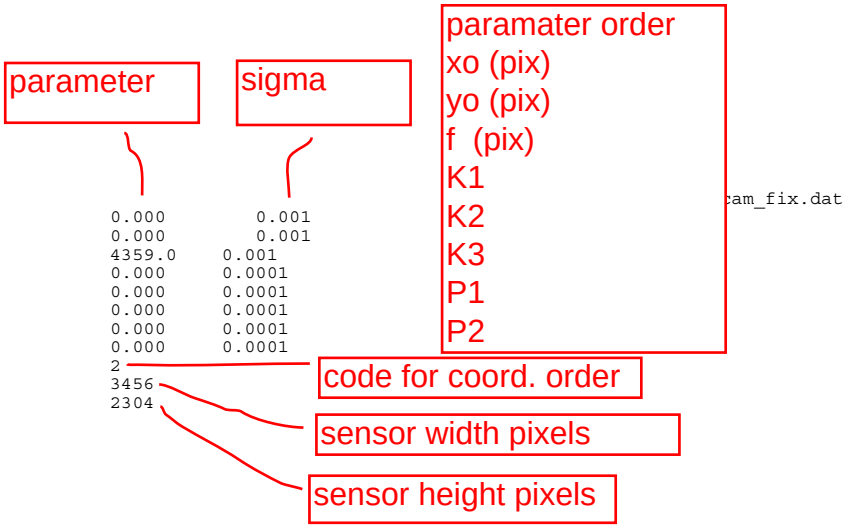
10. if those results are satisfactory, then the estimated calibration parameters
can be found at the end of the listing. again, when satisfied with results,
run again and use the diary command to capture screen output, for turning in.

11. if there are mixups in file names, point ID's, initial approximations,
focal length approximations, etc. it is possible that the nonlinear estimation
will not converge. there is no magic way to fix this other than to go back through the
preparation steps to make sure they are correct. if you run out of ideas about how to fix
a non-converging result, then send me a .zip file with your measurement data, your cam_fix.dat,
your phofiles.dat and your pho.dat files.

12. if you want to add more photos into the estimation, see me about how to do this.
i have a file that you can bring up in arcmap to read off approximate XY coordinates
within mackey arena.




Note, target point 5A has coordinates X=500, Y=1000, Z=10

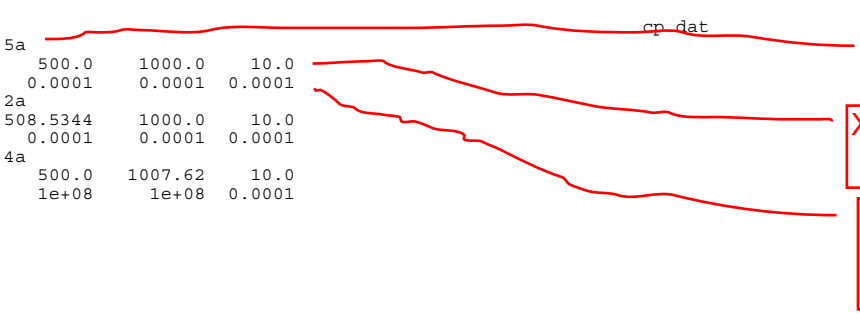

parameter
sigma
paramater order
xo (pix)
yo (pix)
f (pix)
K1
K2
K3
P1
P2
cam_fix.dat
0.000 0.001
0.000 0.001
4359.0 0.001
0.000 0.0001
0.000 0.0001
0.000 0.0001
0.000 0.0001
0.000 0.0001
2
3456
2304
code for coord. order
sensor width pixels
sensor height pixels

format same as cam_fix.dat, only difference is the size of the sigmas, indicating that they are free to be adjusted, rather than fixed (unified LS)

cam_free.dat

```
0.0         1000
0.0         1000
4359.00     1000
0.00000      100
0.00000      100
0.00000      100
0.00000      100
0.00000      100
2
3456
2304
```

control point file - for minimally constrained adjustment (seven coordinate components fixed)



```
img_8146L.txt
img_8147L.txt
img_8148L.txt
img_8149L.txt
img_8150L.txt
img_8151L.txt
img_8152L.txt
img_8153L.txt
```

just a list of the measurement files that you plan to use. the camera station name is taken from the file name minus the extension.

one record for each camera station

camera station name

omega, phi, kappa (rad.) approximations

a priori sigmas, large = unknown

camera station position X,Y,Z

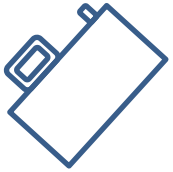
a priori sigmas, large = unknown

pho.dat

```
img_8146L
      1.3115      -0.5004      -0.9120
    1.00e+08     1.00e+08     1.00e+08
       486.4        976.0         16.4
    1.00e+08     1.00e+08     1.00e+08
img_8147L
      1.3115      -0.5004       0.6588
    1.00e+08     1.00e+08     1.00e+08
       486.4        976.0         16.4
    1.00e+08     1.00e+08     1.00e+08
img_8148L
      1.3115       0.5004      -0.6588
    1.00e+08     1.00e+08     1.00e+08
       514.0        976.0         16.4
    1.00e+08     1.00e+08     1.00e+08
img_8149L
      1.3115       0.5004       0.9120
    1.00e+08     1.00e+08     1.00e+08
       514.0        976.0         16.4
    1.00e+08     1.00e+08     1.00e+08
img_8150L
     -1.3115       0.5004       2.2296
    1.00e+08     1.00e+08     1.00e+08
       514.0       1024.2         16.4
    1.00e+08     1.00e+08     1.00e+08
img_8151L
     -1.3115       0.5004      -2.2296
    1.00e+08     1.00e+08     1.00e+08
       514.0       1024.2         16.4
    1.00e+08     1.00e+08     1.00e+08
img_8152L
     -1.3115      -0.5004       2.2296
    1.00e+08     1.00e+08     1.00e+08
       486.4       1024.2         16.4
    1.00e+08     1.00e+08     1.00e+08
img_8153L
     -1.3115      -0.5004      -2.2296
    1.00e+08     1.00e+08     1.00e+08
       486.4       1024.2         16.4
    1.00e+08     1.00e+08     1.00e+08
```

| pos | angle | omega | phi | kappa (radians) |
|---|---|---|---|---|
| 1 | -45 | 1.3115 | -0.5004 | -0.9120 |
| 1 | 45 | 1.3115 | -0.5004 | 0.6588 |
| 2 | -45 | 1.3115 | 0.5004 | -0.6588 |
| 2 | 45 | 1.3115 | 0.5004 | 0.9120 |
| 3 | -45 | -1.3115 | 0.5004 | 2.2296 |
| 3 | 45 | -1.3115 | 0.5004 | -2.4828 |
| 4 | -45 | -1.3115 | -0.5004 | 2.4828 |
| 4 | 45 | -1.3115 | -0.5004 | -2.2296 |
| 1 | 0 | 1.3115 | -0.5004 | -0.1266 |
| 1 | 90 | 1.3115 | -0.5004 | 1.4442 |
| 1 | -90 | 1.3115 | -0.5004 | -1.6974 |
| 2 | 0 | 1.3115 | 0.5004 | 0.1266 |
| 2 | 90 | 1.3115 | 0.5004 | 1.6974 |
| 2 | -90 | 1.3115 | 0.5004 | -1.4442 |
| 3 | 0 | -1.3115 | 0.5004 | 3.0150 |
| 3 | 90 | -1.3115 | 0.5004 | -1.6974 |
| 3 | -90 | -1.3115 | 0.5004 | 1.4442 |
| 4 | 0 | -1.3115 | -0.5004 | -3.0150 |
| 4 | 90 | -1.3115 | -0.5004 | -1.4442 |
| 4 | -90 | -1.3115 | -0.5004 | 1.6974 |
| 5 | 0 | 1.3439 | 0.0000 | -0.0000 |
| 5 | 90 | 1.3439 | 0.0000 | 1.5708 |
| 5 | -90 | 1.3439 | 0.0000 | -1.5708 |
| 6 | 0 | -1.3439 | 0.0000 | 3.1416 |
| 6 | 90 | -1.3439 | 0.0000 | -1.5708 |
| 6 | -90 | -1.3439 | 0.0000 | 1.5708 |
| 7 | 0 | 0.1867 | -1.3398 | -1.3791 |
| 7 | 90 | 0.1867 | -1.3398 | 0.1917 |
| 7 | -90 | 0.1867 | -1.3398 | -2.9499 |
| 8 | 0 | -0.1867 | 1.3398 | 1.7625 |
| 8 | 90 | -0.1867 | 1.3398 | -2.9499 |
| 8 | -90 | -0.1867 | 1.3398 | 0.1917 |

Angle = 0, “landscape”



Angle = +45

Angle = -45

Angle = +90, “portrait” #1

Angle = -90, “portrait” #2

adj_fixed

pba_sc
iter   1 position corrections:   0.245214   1.306320   0.572394
iter   2 position corrections:   0.389626   1.076627   0.423104
iter   3 position corrections:   0.125157   0.150313   0.093207
iter   4 position corrections:   0.013401   0.017203   0.016384
iter   5 position corrections:   0.000616   0.000508   0.000535
iter   6 position corrections:   0.000002   0.000002   0.000001
iter   7 position corrections:   0.000000   0.000000   0.000000
we have converged

observation residuals

photo img_8146L

| | | |
|---|---|---|
| 1a | -2.703 | -2.215 |
| 1b | -3.351 | -2.234 |
| 1c | -2.026 | -2.005 |
| 2a | -3.398 | 0.255 |
| 2b | -3.394 | 0.176 |
| 2c | -2.760 | 0.234 |
| 3a | -2.137 | 0.818 |
| 3b | -2.336 | 0.626 |
| 3c | -1.619 | 0.826 |
| 4a | 5.390 | 0.962 |
| 4b | 4.994 | 0.769 |
| 4c | 5.474 | 1.103 |
| 5a | 4.258 | 0.473 |
| 5b | 4.252 | 0.364 |
| 5c | 4.272 | 0.357 |
| 6a | 3.888 | 0.726 |
| 6b | 3.315 | 0.580 |
| 6c | 3.408 | 0.549 |
| 7a | 1.744 | 2.184 |
| 7b | 1.418 | 2.113 |
| 7c | 1.435 | 2.292 |
| 8a | -2.111 | -0.252 |
| 8b | -2.796 | -0.761 |
| 8c | -3.026 | -0.655 |
| 9a | -2.990 | -2.014 |
| 9b | -2.952 | -1.917 |
| 9c | -3.212 | -2.056 |

photo img_8147L

| | | |
|---|---|---|
| 1a | -3.401 | 0.722 |
| 1b | -3.481 | 0.923 |
| 1c | -2.930 | 0.455 |
| 2a | -1.855 | 2.463 |
| 2b | -1.624 | 2.604 |
| 2c | -1.222 | 2.129 |
| 3a | 0.684 | 1.326 |
| 3b | 0.357 | 1.371 |
| 3c | 0.847 | 1.016 |
| 4a | 3.006 | -2.736 |
| 4b | 2.695 | -2.582 |
| 4c | 2.612 | -2.358 |
| 5a | 1.649 | -2.291 |
| 5b | 1.615 | -2.358 |
| 5c | 1.531 | -2.374 |
| 6a | 1.372 | -2.116 |
| 6b | 1.355 | -1.976 |
| 6c | 1.270 | -1.957 |
| 7a | 3.423 | 0.161 |
| 7b | 3.019 | 0.336 |
| 7c | 2.900 | 0.601 |
| 8a | -1.339 | 1.223 |
| 8b | -1.561 | 1.264 |
| 8c | -1.562 | 1.421 |
| 9a | -2.320 | 0.668 |
| 9b | -2.263 | 0.596 |
| 9c | -2.917 | 0.961 |

photo img_8148L

| | | |
|---|---|---|
| 1a | 0.073 | 0.441 |
| 1b | 0.279 | 0.786 |
| 1c | -0.049 | 0.464 |
| 2a | 2.547 | 1.446 |
| 2b | 2.355 | 1.393 |
| 2c | 2.280 | 1.230 |
| 3a | 1.859 | 0.481 |
| 3b | 1.483 | 0.321 |
| 3c | 1.636 | 0.272 |
| 4a | -6.137 | -2.744 |
| 4b | -6.143 | -2.557 |
| 4c | -6.248 | -2.641 |
| 5a | -2.302 | -1.586 |
| 5b | -2.495 | -1.553 |
| 5c | -2.712 | -1.653 |
| 6a | -2.584 | -2.069 |
| 6b | -2.629 | -2.157 |

| | | |
|---|---|---|
| 6c | -2.983 | -2.282 |
| 7a | 1.434 | -0.470 |
| 7b | 1.769 | 0.043 |
| 7c | 2.379 | 0.498 |
| 8a | 3.234 | 2.036 |
| 8b | 3.220 | 2.085 |
| 8c | 3.786 | 2.437 |
| 9a | 1.069 | 1.668 |
| 9b | 1.013 | 1.701 |
| 9c | 1.671 | 2.032 |

photo img_8149L

| | | |
|---|---|---|
| 1a | 0.245 | 0.446 |
| 1b | 0.211 | 0.678 |
| 1c | -0.167 | 0.536 |
| 2a | 3.038 | -0.412 |
| 2b | 2.596 | -0.190 |
| 2c | 2.194 | -0.241 |
| 3a | 1.987 | -0.835 |
| 3b | 1.524 | -0.672 |
| 3c | 1.466 | -0.723 |
| 4a | -6.785 | 1.477 |
| 4b | -6.190 | 1.383 |
| 4c | -6.365 | 1.553 |
| 5a | -2.571 | 0.062 |
| 5b | -2.904 | 0.204 |
| 5c | -2.974 | 0.350 |
| 6a | -3.369 | -0.229 |
| 6b | -3.334 | -0.287 |
| 6c | -3.417 | -0.195 |
| 7a | 1.918 | -1.346 |
| 7b | 1.718 | -1.187 |
| 7c | 2.080 | -1.238 |
| 8a | 4.278 | -0.388 |
| 8b | 4.021 | -0.156 |
| 8c | 4.494 | -0.230 |
| 9a | 1.662 | 0.727 |
| 9b | 1.164 | 1.005 |
| 9c | 1.755 | 0.854 |

photo img_8150L

| | | |
|---|---|---|
| 1a | -1.111 | -0.978 |
| 1b | -1.440 | -1.440 |
| 1c | -0.913 | -0.963 |
| 2a | -1.575 | -1.874 |
| 2b | -1.876 | -2.036 |
| 2c | -1.366 | -1.592 |
| 3a | -1.694 | -0.357 |
| 3b | -2.350 | -0.436 |
| 3c | -1.278 | 0.036 |
| 4a | 1.307 | 1.671 |
| 4b | 1.561 | 1.426 |
| 4c | 1.490 | 1.335 |
| 5a | 4.130 | 2.610 |
| 5b | 4.383 | 2.628 |
| 5c | 4.212 | 2.507 |
| 6a | 5.927 | 3.489 |
| 6b | 5.749 | 3.460 |
| 6c | 5.875 | 3.398 |
| 7a | -2.392 | -0.415 |
| 7b | -2.147 | -0.461 |
| 7c | -2.678 | -0.571 |
| 8a | -2.856 | -1.348 |
| 8b | -2.867 | -1.607 |
| 8c | -3.405 | -1.739 |
| 9a | -0.685 | -1.667 |
| 9b | -0.324 | -1.763 |
| 9c | -1.093 | -2.117 |

photo img_8151L

| | | |
|---|---|---|
| 1a | -1.325 | 0.475 |
| 1b | -1.503 | 0.178 |
| 1c | -1.319 | 0.181 |
| 2a | -0.804 | -0.423 |
| 2b | -1.039 | -0.234 |
| 2c | -0.798 | -0.363 |
| 3a | 1.142 | 0.505 |
| 3b | 0.524 | 1.000 |
| 3c | 1.235 | 0.604 |
| 4a | 0.271 | -0.525 |
| 4b | 0.058 | -0.454 |
| 4c | 0.184 | -0.739 |
| 5a | 1.513 | -0.515 |
| 5b | 1.470 | -0.574 |
| 5c | 1.680 | -0.575 |
| 6a | 4.310 | -1.369 |
| 6b | 4.254 | -1.385 |
| 6c | 4.414 | -1.405 |

| | | |
|---|---|---|
| 7a | 2.333 | 0.057 |
| 7b | 1.721 | 0.274 |
| 7c | 1.637 | 0.427 |
| 8a | -2.758 | 1.410 |
| 8b | -2.889 | 1.369 |
| 8c | -3.325 | 1.575 |
| 9a | -3.331 | 0.324 |
| 9b | -3.438 | 0.123 |
| 9c | -3.915 | 0.351 |

photo img_8152L

| | | |
|---|---|---|
| 1a | 0.423 | 1.721 |
| 1b | 0.646 | 1.904 |
| 1c | 0.167 | 1.674 |
| 2a | 3.800 | 1.485 |
| 2b | 3.720 | 1.242 |
| 2c | 3.013 | 1.032 |
| 3a | 4.121 | -0.583 |
| 3b | 3.666 | -0.834 |
| 3c | 3.031 | -0.984 |
| 4a | -2.778 | -1.199 |
| 4b | -2.918 | -1.042 |
| 4c | -2.711 | -0.923 |
| 5a | -2.553 | -0.557 |
| 5b | -2.870 | -0.608 |
| 5c | -3.051 | -0.671 |
| 6a | -5.541 | -1.436 |
| 6b | -5.790 | -1.520 |
| 6c | -6.145 | -1.726 |
| 7a | 2.285 | -0.297 |
| 7b | 2.387 | -0.215 |
| 7c | 2.761 | -0.317 |
| 8a | 2.411 | 0.450 |
| 8b | 1.960 | 0.551 |
| 8c | 2.384 | 0.594 |
| 9a | -1.207 | 0.695 |
| 9b | -1.584 | 0.653 |
| 9c | -1.209 | 0.924 |

photo img_8153L

| | | |
|---|---|---|
| 1a | -0.205 | 1.373 |
| 1b | 0.270 | 1.487 |
| 1c | -0.079 | 1.585 |
| 2a | 3.478 | -2.023 |
| 2b | 3.466 | -2.299 |
| 2c | 3.144 | -1.923 |
| 3a | 2.482 | -3.741 |
| 3b | 2.401 | -3.716 |
| 3c | 2.100 | -3.524 |
| 4a | -2.408 | 1.157 |
| 4b | -2.249 | 1.200 |
| 4c | -2.359 | 1.171 |
| 5a | -1.028 | 1.216 |
| 5b | -1.344 | 1.522 |
| 5c | -1.393 | 1.422 |
| 6a | -3.325 | 2.730 |
| 6b | -3.667 | 3.047 |
| 6c | -3.721 | 3.128 |
| 7a | 1.607 | -2.010 |
| 7b | 1.399 | -2.016 |
| 7c | 1.519 | -2.235 |
| 8a | 1.544 | -1.280 |
| 8b | 1.076 | -0.841 |
| 8c | 1.279 | -1.209 |
| 9a | -1.110 | 2.034 |
| 9b | -1.340 | 2.089 |
| 9c | -1.373 | 2.253 |

post adjustment statistics & error propagation

rms-x,rms-y = 2.826 1.504
total coord rms = 2.263726
number of points = 27
number of control points = 3
number of observations = 432
number of photos = 8
redundancy = 312
post-adj sigma-nought squared = 7.10

exterior orientation data for photos

photo img_8146L

w,p,k 1.304153 -0.204534 -0.285865
x,y,z 494.699 972.144 17.864

photo img_8147L

w,p,k 1.287734 -0.189484 0.493083

adj_fixed

x,y,z  494.653  972.093  17.900

photo img_8148L

w,p,k  1.268257  0.503423  -0.263487
x,y,z  513.969  975.697  17.742

photo img_8149L

w,p,k  1.266985  0.498085  0.364615
x,y,z  513.968  975.681  17.763

photo img_8150L

w,p,k  -1.309696  0.542797  2.715477
x,y,z  513.825  1024.959  17.811

photo img_8151L

w,p,k  -1.277021  0.501562  -2.757354
x,y,z  513.746  1024.931  17.831

photo img_8152L

w,p,k  -1.259501  -0.542895  2.886484
x,y,z  484.813  1023.859  17.707

photo img_8153L

w,p,k  -1.263063  -0.536210  -2.468639
x,y,z  484.068  1024.330  17.899

point coordinates

| | | | |
|---|---|---|---|
| 1a | 508.564 | 1007.016 | 9.996 |
| 1b | 508.568 | 1006.616 | 9.997 |
| 1c | 508.229 | 1006.616 | 9.994 |
| 2a | 508.534 | 1000.000 | 10.000 |
| 2b | 508.530 | 999.594 | 9.999 |
| 2c | 508.192 | 999.599 | 9.999 |
| 3a | 508.508 | 994.663 | 10.009 |
| 3b | 508.507 | 994.258 | 10.012 |
| 3c | 508.170 | 994.255 | 10.008 |
| 4a | 499.917 | 1007.091 | 10.000 |
| 4b | 499.912 | 1006.688 | 10.000 |
| 4c | 499.568 | 1006.693 | 9.999 |
| 5a | 500.000 | 1000.000 | 10.000 |
| 5b | 499.991 | 999.591 | 9.998 |
| 5c | 499.643 | 999.599 | 9.998 |
| 6a | 499.978 | 994.605 | 10.007 |
| 6b | 499.978 | 994.196 | 10.008 |
| 6c | 499.632 | 994.194 | 10.007 |
| 7a | 491.389 | 1007.094 | 10.015 |
| 7b | 491.389 | 1006.690 | 10.011 |
| 7c | 491.048 | 1006.686 | 10.014 |
| 8a | 491.336 | 1000.110 | 10.006 |
| 8b | 491.330 | 999.704 | 10.006 |
| 8c | 490.992 | 999.714 | 10.007 |
| 9a | 491.422 | 994.730 | 10.011 |
| 9b | 491.432 | 994.327 | 10.011 |
| 9c | 491.095 | 994.328 | 10.011 |

refined camera parameters

x0  -0.000
y0  -0.000
foc  4359.000
k1 0.00010908332
k2 0.00011243893
k3 7.4050879e-05
p1 -2.6100495e-07
p2 -1.201141e-07
cond(N) before Wts  1.8571493e+17
cond(N) after Wts  3946666.2

diary off

```
                                                          adj_free
pba_sc
iter   1 position corrections:   0.205320   1.712748   0.695307
iter   2 position corrections:   0.686002   2.030633   0.492896
iter   3 position corrections:   0.285659   0.571433   0.076495
iter   4 position corrections:   0.094471   0.151167   0.039076
iter   5 position corrections:   0.005453   0.008174   0.003424
iter   6 position corrections:   0.000230   0.000256   0.000064
iter   7 position corrections:   0.000003   0.000011   0.000002
iter   8 position corrections:   0.000000   0.000000   0.000000
we have converged

observation residuals

photo img_8146L

        1a     -0.013     -0.031
        1b     -0.514     -0.335
        1c      0.252     -0.195
        2a      0.165      0.043
        2b      0.116     -0.098
        2c      0.144     -0.108
        3a      0.028      0.106
        3b     -0.332     -0.090
        3c     -0.138      0.066
        4a      0.208      0.286
        4b     -0.127      0.070
        4c      0.280      0.292
        5a     -0.034      0.089
        5b      0.006      0.012
        5c      0.077      0.058
        6a      0.357      0.267
        6b     -0.129      0.039
        6c     -0.023      0.021
        7a     -0.032     -0.022
        7b      0.007     -0.011
        7c      0.160      0.035
        8a      0.209      0.152
        8b     -0.344     -0.189
        8c     -0.286     -0.101
        9a     -0.064     -0.178
        9b     -0.072     -0.098
        9c      0.165     -0.070

photo img_8147L

        1a     -0.021      0.050
        1b     -0.222     -0.037
        1c     -0.045     -0.183
        2a     -0.068     -0.150
        2b      0.044      0.010
        2c      0.070     -0.094
        3a      0.297     -0.115
        3b     -0.270      0.120
        3c      0.019      0.041
        4a      0.219      0.035
        4b     -0.051      0.136
        4c     -0.282      0.345
        5a     -0.100      0.197
        5b     -0.071      0.131
        5c     -0.086      0.116
        6a      0.140     -0.075
        6b      0.122     -0.042
        6c      0.074     -0.048
        7a      0.284     -0.141
        7b      0.187     -0.161
        7c     -0.028     -0.065
        8a      0.018     -0.070
        8b     -0.015     -0.001
        8c      0.020     -0.022
        9a      0.109     -0.035
        9b      0.075     -0.087
        9c     -0.436      0.116

photo img_8148L

        1a      0.249      0.011
        1b      0.121      0.037
        1c      0.132     -0.042
        2a     -0.074     -0.032
        2b     -0.289     -0.009
        2c     -0.128      0.005
        3a      0.065      0.084
        3b     -0.150     -0.036
        3c      0.160      0.006
        4a      0.189     -0.008
        4b     -0.159      0.039
        4c     -0.309     -0.041
        5a      0.437      0.060
        5b      0.174      0.093
        5c      0.021     -0.005
        6a      0.000     -0.033
```

| | | |
|---|---|---|
| 6b | -0.005 | -0.042 |
| 6c | -0.224 | -0.131 |
| 7a | -0.158 | -0.210 |
| 7b | -0.044 | 0.026 |
| 7c | -0.035 | 0.193 |
| 8a | -0.147 | -0.149 |
| 8b | -0.109 | -0.127 |
| 8c | -0.102 | -0.051 |
| 9a | -0.095 | -0.018 |
| 9b | 0.136 | 0.119 |
| 9c | 0.287 | 0.162 |

photo img_8149L

| | | |
|---|---|---|
| 1a | 0.497 | -0.139 |
| 1b | -0.009 | 0.032 |
| 1c | -0.018 | -0.096 |
| 2a | 0.172 | -0.184 |
| 2b | -0.257 | 0.115 |
| 2c | -0.388 | 0.085 |
| 3a | 0.275 | -0.143 |
| 3b | -0.043 | -0.032 |
| 3c | 0.065 | -0.088 |
| 4a | -0.322 | 0.101 |
| 4b | -0.093 | 0.095 |
| 4c | -0.316 | 0.298 |
| 5a | 0.312 | -0.072 |
| 5b | -0.072 | 0.113 |
| 5c | -0.087 | 0.221 |
| 6a | -0.175 | 0.061 |
| 6b | -0.033 | 0.045 |
| 6c | 0.037 | 0.077 |
| 7a | 0.467 | -0.154 |
| 7b | -0.064 | -0.094 |
| 7c | -0.349 | -0.034 |
| 8a | 0.231 | -0.225 |
| 8b | 0.023 | -0.051 |
| 8c | -0.109 | -0.029 |
| 9a | 0.138 | -0.086 |
| 9b | -0.007 | 0.099 |
| 9c | 0.039 | -0.003 |

photo img_8150L

| | | |
|---|---|---|
| 1a | 0.254 | 0.134 |
| 1b | -0.199 | -0.062 |
| 1c | 0.156 | 0.204 |
| 2a | 0.027 | 0.158 |
| 2b | -0.209 | -0.089 |
| 2c | -0.144 | 0.057 |
| 3a | 0.402 | 0.098 |
| 3b | -0.301 | -0.111 |
| 3c | 0.091 | 0.032 |
| 4a | -0.089 | 0.002 |
| 4b | -0.073 | -0.259 |
| 4c | -0.181 | -0.303 |
| 5a | 0.000 | 0.007 |
| 5b | 0.147 | -0.055 |
| 5c | -0.025 | -0.203 |
| 6a | 0.202 | -0.060 |
| 6b | -0.135 | -0.137 |
| 6c | -0.150 | -0.165 |
| 7a | -0.027 | 0.119 |
| 7b | 0.209 | 0.056 |
| 7c | 0.140 | 0.107 |
| 8a | 0.050 | 0.069 |
| 8b | 0.008 | -0.128 |
| 8c | -0.005 | 0.035 |
| 9a | -0.033 | 0.164 |
| 9b | -0.031 | 0.087 |
| 9c | -0.181 | 0.096 |

photo img_8151L

| | | |
|---|---|---|
| 1a | 0.079 | 0.119 |
| 1b | -0.055 | 0.099 |
| 1c | 0.108 | 0.046 |
| 2a | 0.279 | -0.070 |
| 2b | -0.048 | 0.035 |
| 2c | 0.032 | -0.046 |
| 3a | 0.250 | -0.149 |
| 3b | -0.596 | 0.337 |
| 3c | -0.074 | 0.043 |
| 4a | 0.081 | -0.284 |
| 4b | -0.151 | -0.151 |
| 4c | -0.197 | -0.311 |
| 5a | -0.131 | 0.113 |
| 5b | -0.326 | 0.062 |
| 5c | -0.095 | 0.034 |
| 6a | 0.302 | -0.257 |
| 6b | 0.044 | -0.184 |

| | | |
|---|---|---|
| 6c | 0.252 | -0.116 |
| 7a | 0.126 | 0.182 |
| 7b | -0.040 | 0.146 |
| 7c | -0.036 | 0.163 |
| 8a | 0.063 | -0.059 |
| 8b | 0.113 | -0.099 |
| 8c | 0.068 | -0.069 |
| 9a | 0.102 | 0.052 |
| 9b | -0.128 | 0.084 |
| 9c | -0.062 | 0.109 |

photo img_8152L

| | | |
|---|---|---|
| 1a | 0.122 | 0.038 |
| 1b | 0.027 | 0.065 |
| 1c | -0.097 | 0.032 |
| 2a | -0.132 | -0.017 |
| 2b | -0.319 | -0.154 |
| 2c | -0.488 | -0.203 |
| 3a | 0.246 | 0.064 |
| 3b | -0.070 | 0.064 |
| 3c | -0.069 | 0.050 |
| 4a | 0.088 | -0.170 |
| 4b | -0.106 | -0.071 |
| 4c | 0.012 | 0.003 |
| 5a | 0.603 | 0.100 |
| 5b | 0.391 | 0.066 |
| 5c | 0.223 | 0.011 |
| 6a | 0.043 | 0.013 |
| 6b | 0.079 | 0.061 |
| 6c | -0.181 | -0.166 |
| 7a | -0.002 | -0.055 |
| 7b | -0.027 | 0.102 |
| 7c | -0.107 | -0.031 |
| 8a | 0.021 | 0.029 |
| 8b | -0.275 | 0.057 |
| 8c | -0.295 | -0.022 |
| 9a | 0.079 | -0.081 |
| 9b | 0.077 | -0.038 |
| 9c | 0.108 | 0.065 |

photo img_8153L

| | | |
|---|---|---|
| 1a | 0.005 | -0.240 |
| 1b | -0.029 | 0.119 |
| 1c | -0.103 | 0.120 |
| 2a | -0.044 | 0.018 |
| 2b | -0.097 | -0.088 |
| 2c | -0.018 | -0.006 |
| 3a | 0.006 | -0.171 |
| 3b | 0.168 | -0.086 |
| 3c | 0.308 | -0.280 |
| 4a | 0.182 | 0.050 |
| 4b | 0.141 | 0.132 |
| 4c | -0.135 | 0.206 |
| 5a | 0.099 | -0.064 |
| 5b | -0.160 | 0.170 |
| 5c | -0.206 | 0.078 |
| 6a | -0.023 | -0.088 |
| 6b | -0.059 | 0.068 |
| 6c | -0.031 | 0.048 |
| 7a | 0.142 | -0.238 |
| 7b | -0.034 | -0.139 |
| 7c | -0.076 | -0.153 |
| 8a | 0.250 | -0.051 |
| 8b | -0.147 | 0.220 |
| 8c | -0.169 | 0.032 |
| 9a | -0.030 | 0.103 |
| 9b | 0.075 | -0.100 |
| 9c | -0.092 | 0.115 |

post adjustment statistics & error propagation

rms-x,rms-y = 0.186 0.125
total coord rms = 0.158499
number of points = 27
number of control points = 3
number of observations = 432
number of photos = 8
redundancy = 312
post-adj sigma-nought squared = 0.03

exterior orientation data for photos

photo img_8146L

w,p,k 1.311717 -0.202036 -0.283298
x,y,z 494.613 971.615 17.847

photo img_8147L

```
w,p,k     1.293209    -0.186232     0.495355
x,y,z      494.561      971.551       17.882

photo img_8148L

w,p,k     1.273821     0.502172    -0.262950
x,y,z      514.163      975.071       17.854

photo img_8149L

w,p,k     1.270353     0.497765     0.366215
x,y,z      514.160      975.053       17.874

photo img_8150L

w,p,k    -1.314856     0.536312     2.715825
x,y,z      513.949     1025.443       17.878

photo img_8151L

w,p,k    -1.280603     0.494189    -2.757302
x,y,z      513.885     1025.440       17.893

photo img_8152L

w,p,k    -1.264425    -0.541672     2.884507
x,y,z      484.613     1024.443       17.839

photo img_8153L

w,p,k    -1.264363    -0.536061    -2.468792
x,y,z      483.848     1024.939       18.037

point coordinates

        1a      508.579     1007.133       10.003
        1b      508.581     1006.722       10.003
        1c      508.236     1006.719       10.000
        2a      508.534     1000.000       10.000
        2b      508.530      999.589        9.999
        2c      508.187      999.594        9.998
        3a      508.519      994.599       10.002
        3b      508.520      994.188       10.005
        3c      508.177      994.188       10.000
        4a      499.928     1007.124       10.000
        4b      499.921     1006.716       10.000
        4c      499.581     1006.720        9.999
        5a      500.000     1000.000       10.000
        5b      499.991      999.590        9.997
        5c      499.647      999.598        9.997
        6a      499.974      994.586        9.996
        6b      499.973      994.174        9.996
        6c      499.629      994.170        9.995
        7a      491.413     1007.131        9.993
        7b      491.415     1006.719        9.989
        7c      491.070     1006.716        9.991
        8a      491.361     1000.066        9.988
        8b      491.354      999.656        9.987
        8c      491.010      999.664        9.987
        9a      491.420      994.626        9.986
        9b      491.426      994.216        9.986
        9c      491.084      994.212        9.985

refined camera parameters

x0      -14.103
y0        7.480
foc     4488.748
k1  0.039772269
k2 -0.047411685
k3  0.032820318
p1 -0.080421516
p2  -0.51584645
cond(N) before Wts  3.8733237e+17
cond(N) after Wts  6.9786146e+10


diary off
```