Photogrammetry HW4 assigned Thur. 28 Feb, 2013
due Tues. 19 Mar.

1. Camera Calibration

(a) download code & template data files from HW web page.

(b) assemble all files into a single folder including your 8 (+) measurement files (from HW 3) and a single pho.dat which contains a 5-line entry for each image (created by apx_eo.m)

(c) enter approximate focal length (from HW 1) for your camera into cam_fix.dat; cam_free.dat. Then copy cam_fix.dat to cam.dat.

(d) enter all measurement filenames into photfiles.dat in the same order as pho.dat. (for all text file preparation use notepad or equivalent text editor)

(e) enter 3 points from your reference coordinate system into cp.dat. Typical entries:

4a	0.000	0.000	0.000
	0.0001	0.0001	0.0001
2a	X.XXX	0.000	0.000
	0.0001	0.0001	0.0001
6a	0.000	Y.YYY	0.000
	1e+08	1e+08	0.0001

These consitute a set of minimal constraints.

(f) Run pba-sc to confirm convergence, point ID's, and initial approximations. Expectation ~5 iterations with RMS for x & y around 3-8 pixels.

(g) If step (f) successful, copy cam_free.dat to cam.dat and run pba-sc.m again, this time estimating the free I/O parameters. Expectation ~5-10 iterations with RMS for x & y around 0.1 – 0.2 pixels.

(h) calibration parameters are at the end of output listing. Capture output listing into a log file.

(i) Submit all data & listing files
See accompanying annotated file listings.

2. Relative Orientation

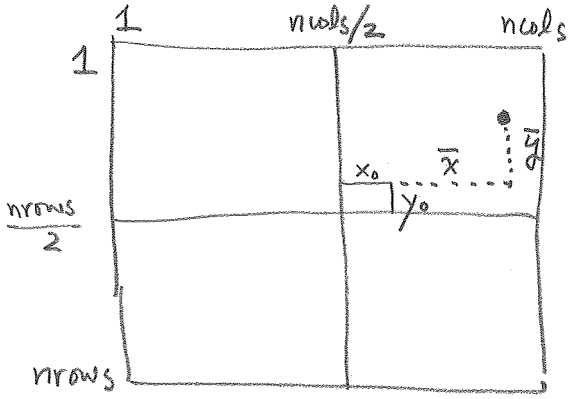
(a) capture 2 images of a scene/object with a B/H ratio of approximately 0.15 – 0.20. Use "approximately" the same object distance as in calibration. H can be longer if we assume lens focus setting was ∞ for calibration. Also Max Resolution!

(b) measure at least 8 conjugate points in each of the 2 photos. Recommend imeas.m.

(c) convert (s, l) or (c, r) to x, y cartesian:

$$\bar{x} = c - \frac{ncols}{2} - x_0$$

$$\bar{y} = -\left(r - \frac{nrows}{2}\right) - y_0$$



(d) program 8 point algorithm with unique or LS solution. Refine your image coordinates with your lens distortion corrections. Obtain $b_x, b_y, b_z, \omega, \varphi, \kappa$

(e) program relative orientation by coplanarity, either use your refined coordinates directly or put the refinement into coplan.m. Fix b_x as found in (d)

(f) compare $b_y, b_z, \omega, \varphi, \kappa$ for 2 approaches.

(g) produce anaglyph stereo viewer. I will provide some code to do this (not quite ready yet!)

files needed for bundle block adjustment

matlab code

- pba_sc.m
- gencof.m
- gndx.m
- collin.m
- int_leq2.m

data files

- cam.dat
- (cam_fix.dat, cam_free.dat)
- cp.dat
- delta.dat
- pho.dat
- phofiles.dat
- sig.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
```

```
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
```

```
4a
0.000  0.000  0.000
0.0001 0.0001 0.0001
2a
1.838  0.000  0.000
0.0001 0.0001 0.0001
6a
0.000  1.838  0.000
1e+08  1e+08  0.0001
```

```
img_7181
   0.8356914    0.7029320    0.5240716
    1.00e+08     1.00e+08     1.00e+08
       4.992       -2.804        2.830
    1.00e+08     1.00e+08     1.00e+08
img_7182
   0.9007947    0.6993645    2.0252924
    1.00e+08     1.00e+08     1.00e+08
       5.012       -2.791        2.908
    1.00e+08     1.00e+08     1.00e+08
img_7183
  -0.9221732    0.6255621    2.7080037
    1.00e+08     1.00e+08     1.00e+08
       3.876        4.187        2.548
    1.00e+08     1.00e+08     1.00e+08
img_7184
  -0.7958648    0.6055263   -1.7990338
    1.00e+08     1.00e+08     1.00e+08
       3.926        4.220        2.649
    1.00e+08     1.00e+08     1.00e+08
img_7185
  -0.7851171   -0.6004826   -2.6302883
    1.00e+08     1.00e+08     1.00e+08
      -2.056        4.095        2.600
    1.00e+08     1.00e+08     1.00e+08
img_7186
  -0.7287907   -0.5831348   -0.7057403
    1.00e+08     1.00e+08     1.00e+08
      -2.574        4.441        2.955
    1.00e+08     1.00e+08     1.00e+08
img_7187
   0.9580076   -0.7331735   -0.4196984
    1.00e+08     1.00e+08     1.00e+08
      -2.675       -2.274        2.841
    1.00e+08     1.00e+08     1.00e+08
img_7188
   0.7811358   -0.6079952    0.6143526
    1.00e+08     1.00e+08     1.00e+08
      -2.684       -2.250        2.874
    1.00e+08     1.00e+08     1.00e+08
img_7189
   0.9586305   -0.7407600    0.7605801
    1.00e+08     1.00e+08     1.00e+08
      -2.678       -2.261        2.880
    1.00e+08     1.00e+08     1.00e+08
```

img_7181.txt
img_7182.txt
img_7183.txt
img_7184.txt
img_7185.txt
img_7186.txt
img_7187.txt
img_7188.txt
img_7189.txt

```
pba_sc
iter   1 position corrections:   0.063433   0.068889   0.309012
iter   2 position corrections:   0.009699   0.008414   0.015132
iter   3 position corrections:   0.003557   0.003634   0.010452
iter   4 position corrections:   0.000005   0.000055   0.000028
iter   5 position corrections:   0.000000   0.000000   0.000000
we have converged

observation residuals

photo img_7181

        1a     -4.170     -0.900
        1b     -1.464     -0.266
        1c     -3.948     -1.146
        2a      0.459     -0.959
        2b     -0.155     -0.756
        2c      0.217     -0.708
        3a      2.362     -0.640
        3b      3.755     -0.703
        3c      2.155     -0.411
        4a      1.207      1.765
        4b      1.075      1.635
        4c      0.689      1.683
        5a     -0.153      0.673
        5b     -0.666      0.575
        5c     -0.349      0.742
        6a     -0.457      0.979
        6b     -0.595      0.971
        6c     -0.057      0.837
        7a      7.267     -0.444
        7b      6.291     -0.364
        7c      6.461     -0.068
        8a     -0.105     -0.945
        8b     -0.761     -0.863
        8c     -0.290     -0.589
        9a     -5.729      0.203
        9b     -6.914      0.197
        9c     -5.785      0.623

photo img_7182

        1b     -1.792      6.243
        2a     -1.190      0.248
        2b     -0.920      0.340
        2c     -1.215      0.435
        3a     -1.139     -3.998
        3c     -1.225     -4.024
        4a      1.486      0.488
        4b      1.574      0.510
        4c      1.563      1.129
        5a      1.632      0.022
        5b      1.636      0.237
        5c      1.795      0.075
        6a      1.215     -0.075
        6b      1.164      0.183
        6c      1.216     -0.484
        7a     -0.898     -7.265
        7b     -0.733     -6.407
        7c     -0.520     -6.521
        8a     -0.820     -0.321
        8b     -0.828      0.301
        8c     -0.345     -0.037
```

9a	-0.306	5.968
9b	-0.493	7.079
9c	0.089	5.873

photo img_7183

1a	7.154	1.047
1b	6.855	0.773
1c	7.242	1.289
2a	2.037	1.140
2b	2.052	0.436
2c	2.110	0.888
3a	-3.820	-0.470
3b	-5.034	-1.884
3c	-4.540	-0.459
4a	0.424	-0.583
4b	0.434	-0.276
4c	1.340	-0.481
5a	-0.232	-0.402
5b	0.164	-0.428
5c	0.252	-0.576
6a	1.064	-0.526
6b	1.288	-0.418
6c	1.140	-0.536
7a	-7.716	0.721
7b	-6.906	0.923
7c	-6.835	0.776
8a	-1.799	0.794
8b	-1.286	0.563
8c	-1.676	0.581
9a	2.440	-0.359
9b	2.658	0.020
9c	2.242	-0.373

photo img_7184

1a	1.713	-2.816
1b	1.527	-2.279
1c	2.294	-2.553
4a	-1.617	-1.148
4b	-1.486	-1.087
4c	-1.578	-1.637
5a	-1.501	0.806
5b	-1.715	0.641
5c	-1.622	0.891
6a	-0.633	2.027
6b	-0.201	2.109
6c	-0.424	2.555
7a	1.229	4.116
7b	1.331	3.399
7c	1.067	3.380
8a	0.324	-0.375
8b	0.095	-0.726
8c	-0.065	-0.460
9a	0.466	-2.309
9b	1.066	-2.537
9c	0.340	-2.033

photo img_7185

1a	-7.506	-0.338
1b	-8.206	-0.479
1c	-7.551	-0.701

2a	0.670	-1.451
2b	0.574	-1.195
2c	0.590	-1.669
3a	8.165	1.946
3b	7.721	2.392
3c	8.811	1.910
4a	-1.950	1.294
4b	-1.914	1.231
4c	-2.541	1.116
5a	1.356	0.719
5b	1.433	0.621
5c	1.367	0.756
6a	1.505	1.395
6b	0.809	1.489
6c	1.738	1.702
7a	2.260	0.341
7b	2.001	0.315
7c	2.132	0.382
8a	1.568	-0.453
8b	1.614	-0.583
8c	1.601	-0.409
9a	-4.093	-2.525
9b	-5.982	-3.004
9c	-4.655	-2.269

photo img_7186

1a	1.795	3.674
1b	1.898	4.821
1c	1.472	4.016
2a	-1.395	0.490
2b	-1.110	1.048
2c	-1.545	0.873
3a	-0.537	-5.406
3b	0.015	-5.051
3c	-0.701	-5.804
4a	0.876	-1.048
4b	0.720	-0.738
4c	0.898	-0.425
5a	-0.685	0.718
5b	-0.586	1.121
5c	-0.482	0.791
6a	1.380	1.100
6b	1.858	1.384
6c	1.549	0.562
7a	-0.364	-2.970
7b	-0.430	-2.129
7c	-0.573	-2.676
8a	-1.067	1.879
8b	-0.873	2.157
8c	-1.050	1.898

photo img_7187

1a	3.665	-1.414
1b	1.980	0.403
1c	3.730	-1.219
2a	-2.460	1.481
2b	-2.249	1.358
2c	-2.623	1.398
3a	-6.226	-0.510
3b	-6.659	-0.633
3c	-7.024	-0.614

4a	0.102	-0.196
4b	0.304	-0.032
4c	0.412	0.008
5a	1.003	1.262
5b	1.366	1.365
5c	0.957	1.222
6a	0.958	-0.294
6b	1.108	-0.958
6c	0.398	-0.611
7a	-3.617	-1.915
7b	-3.276	-1.550
7c	-2.931	-1.615
8a	0.286	0.890
8b	0.833	1.103
8c	0.656	1.047
9a	6.153	0.813
9b	7.165	0.425
9c	6.183	0.466

photo img_7188

2a	2.462	-3.356
2b	2.601	-3.466
2c	3.208	-3.729
3a	1.203	1.648
3b	1.108	2.160
3c	1.489	1.845
4a	-2.436	0.512
4b	-3.048	0.333
4c	-2.713	0.181
5a	-3.535	0.776
5b	-3.126	0.657
5c	-3.278	0.356
6a	-2.728	1.764
6b	-2.832	1.849
6c	-2.768	1.981
7a	4.510	-0.590
7b	3.231	-0.383
7c	3.243	-0.337
8a	-0.159	0.773
8b	-0.109	0.806
8c	-0.695	0.946
9a	1.303	-0.854
9b	1.514	-1.734
9c	0.926	-0.870

photo img_7189

2a	1.318	0.354
2b	1.274	0.471
2c	1.225	0.515
3a	-2.886	5.124
3b	-3.450	5.513
3c	-3.464	5.699
4a	0.139	-2.762
4b	0.458	-2.601
4c	0.517	-3.008
5a	2.330	-0.711
5b	2.420	-0.749
5c	2.262	-0.804
6a	-0.406	-0.491
6b	-0.993	-0.754
6c	-1.020	0.096

7a	-3.924	3.551
7b	-3.297	3.179
7c	-3.254	2.776
8a	1.324	0.599
8b	1.609	0.207
8c	1.600	0.243
9a	2.699	-5.239
9b	2.712	-6.451
9c	2.457	-5.224

post adjustment statistics & error propagation

rms-x,rms-y = 2.943 2.153
total coord rms = 2.578226
number of points = 27
number of control points = 3
number of observations = 450
number of photos = 9
redundancy = 324
post-adj sigma-nought squared = 9.23

exterior orientation data for photos

photo img_7181

w,p,k	0.956370	0.753192	0.445634
x,y,z	4.993	-2.803	2.796

photo img_7182

w,p,k	1.030247	0.744480	1.941106
x,y,z	5.031	-2.815	2.867

photo img_7183

w,p,k	-0.905597	0.606035	2.702441
x,y,z	3.870	4.187	2.563

photo img_7184

w,p,k	-0.800368	0.629967	-1.790315
x,y,z	3.904	4.202	2.611

photo img_7185

w,p,k	-0.894576	-0.643143	-2.692902
x,y,z	-2.043	4.075	2.607

photo img_7186

w,p,k	-0.843896	-0.636739	-0.770597
x,y,z	-2.527	4.384	2.952

photo img_7187

w,p,k	0.896848	-0.735531	-0.462433
x,y,z	-2.648	-2.275	2.857

photo img_7188

w,p,k	0.756611	-0.591790	0.597296
x,y,z	-2.676	-2.264	2.866

photo img_7189

w,p,k	0.908935	-0.744472	0.725604
x,y,z	-2.654	-2.253	2.887

point coordinates

1a	0.918	-0.908	-0.011
1b	1.020	-0.810	-0.011
1c	1.030	-0.935	-0.012
2a	1.838	0.000	0.000
2b	1.935	0.101	0.002
2c	1.950	-0.022	-0.001
3a	2.744	0.917	-0.009
3b	2.845	1.015	-0.008
3c	2.854	0.889	-0.009
4a	0.000	-0.000	-0.000
4b	0.099	0.098	-0.001
4c	0.112	-0.026	-0.000
5a	0.922	0.949	0.127
5b	1.021	1.049	0.126
5c	1.036	0.924	0.127
6a	1.830	1.839	0.000
6b	1.927	1.939	0.000
6c	1.943	1.815	-0.000
7a	-0.909	0.923	0.008
7b	-0.805	1.014	0.007
7c	-0.802	0.889	0.007
8a	0.001	1.835	0.011
8b	0.099	1.935	0.011
8c	0.113	1.811	0.010
9a	0.919	2.755	0.012
9b	1.018	2.852	0.013
9c	1.031	2.730	0.011

refined camera parameters

x0	-0.000
y0	-0.000
foc	4359.000
k1	0.00044993312
k2	0.00043645441
k3	0.00028863642
p1	-6.4200745e-07
p2	-8.150224e-07
cond(N) before Wts	4.3177236e+14
cond(N) after Wts	68845.257

diary off

```
pba_sc
iter   1 position corrections:   0.068996   0.080927   0.287974
iter   2 position corrections:   0.045308  -0.049061   0.030490
iter   3 position corrections:   0.057774   0.042677   0.041763
iter   4 position corrections:   0.013718   0.017113   0.014044
iter   5 position corrections:   0.005371   0.003740   0.004691
iter   6 position corrections:   0.000929   0.000830   0.000840
iter   7 position corrections:   0.000033   0.000035   0.000034
iter   8 position corrections:   0.000004   0.000003   0.000003
iter   9 position corrections:   0.000000   0.000000   0.000000
we have converged

observation residuals

photo img_7181

        1a     -0.039     -0.005
        1b      0.109      0.150
        1c      0.070     -0.003
        2a      0.303     -0.390
        2b     -0.435      0.004
        2c     -0.032     -0.098
        3a      0.170     -0.010
        3b     -0.009      0.084
        3c      0.006      0.019
        4a     -0.004      0.035
        4b      0.099      0.070
        4c     -0.096      0.056
        5a      0.172      0.094
        5b     -0.305      0.012
        5c     -0.024      0.237
        6a     -0.031      0.083
        6b     -0.088     -0.015
        6c      0.013     -0.004
        7a     -0.029     -0.127
        7b     -0.017     -0.000
        7c      0.020     -0.088
        8a     -0.003     -0.005
        8b     -0.015      0.034
        8c      0.093      0.014
        9a      0.225     -0.028
        9b     -0.128     -0.164
        9c     -0.029      0.049

photo img_7182

        1b     -0.062      0.109
        2a     -0.226     -0.404
        2b      0.144      0.232
        2c     -0.024     -0.042
        3a      0.092     -0.013
        3c      0.074      0.142
        4a     -0.021     -0.079
        4b      0.081     -0.083
        4c      0.116      0.047
        5a     -0.073     -0.061
        5b     -0.076      0.193
        5c      0.115     -0.001
        6a     -0.053     -0.056
        6b     -0.064      0.114
        6c      0.041     -0.037
        7a     -0.038      0.072
        7b      0.053      0.025
```

7c	-0.105	-0.108
8a	0.066	0.160
8b	0.028	0.105
8c	0.111	0.138
9a	0.025	-0.227
9b	-0.175	-0.035
9c	0.026	-0.133

photo img_7183

1a	0.056	-0.035
1b	0.096	-0.057
1c	0.015	-0.067
2a	-0.405	0.400
2b	0.518	-0.140
2c	0.101	0.046
3a	-0.123	0.063
3b	0.022	0.015
3c	0.061	0.015
4a	-0.148	-0.065
4b	-0.074	-0.005
4c	0.128	-0.046
5a	-0.197	0.122
5b	0.192	0.184
5c	0.022	0.022
6a	0.000	-0.195
6b	0.000	-0.144
6c	-0.135	-0.172
7a	-0.093	0.019
7b	0.045	-0.054
7c	-0.046	0.052
8a	0.048	0.029
8b	-0.034	-0.009
8c	-0.099	-0.028
9a	0.013	-0.011
9b	0.105	0.191
9c	0.039	-0.016

photo img_7184

1a	0.141	0.163
1b	0.055	0.058
1c	0.161	0.164
4a	0.030	-0.007
4b	-0.018	-0.040
4c	-0.002	-0.211
5a	-0.137	0.254
5b	-0.230	-0.111
5c	-0.329	0.075
6a	0.063	-0.022
6b	0.100	-0.123
6c	0.024	0.028
7a	-0.085	-0.041
7b	-0.044	-0.126
7c	0.071	-0.101
8a	0.034	-0.023
8b	0.001	-0.011
8c	0.010	-0.082
9a	0.088	0.228
9b	0.147	-0.079
9c	0.018	0.016

photo img_7185

1a	-0.030	-0.063
1b	-0.044	0.008
1c	0.060	-0.046
2a	0.608	-0.088
2b	-0.498	-0.076
2c	0.056	-0.078
3a	0.043	-0.065
3b	-0.027	0.002
3c	-0.121	-0.040
4a	0.058	0.079
4b	-0.037	0.090
4c	-0.100	-0.040
5a	0.275	0.238
5b	-0.038	0.086
5c	0.157	0.292
6a	0.063	0.030
6b	-0.093	0.047
6c	0.034	0.089
7a	-0.221	0.127
7b	-0.018	0.052
7c	0.021	0.034
8a	0.020	-0.195
8b	0.001	-0.157
8c	0.067	-0.205
9a	0.135	0.102
9b	-0.217	-0.163
9c	0.018	0.106

photo img_7186

1a	-0.064	-0.056
1b	0.095	0.037
1c	-0.130	-0.119
2a	-0.075	-0.596
2b	0.239	0.553
2c	0.039	0.009
3a	-0.065	-0.190
3b	0.073	0.085
3c	0.092	0.193
4a	0.027	0.000
4b	0.097	-0.051
4c	-0.004	0.110
5a	-0.215	0.057
5b	-0.178	0.379
5c	-0.076	0.142
6a	0.014	-0.137
6b	0.123	0.045
6c	0.052	-0.240
7a	0.039	-0.147
7b	0.144	0.013
7c	-0.027	-0.020
8a	-0.051	0.014
8b	0.083	-0.010
8c	0.010	-0.003

photo img_7187

1a	-0.071	0.049
1b	0.041	-0.110
1c	-0.048	0.075
2a	-0.226	0.176
2b	0.230	0.047

2c	0.100	0.096
3a	-0.091	-0.111
3b	-0.021	-0.021
3c	0.055	-0.024
4a	-0.100	-0.164
4b	-0.069	-0.210
4c	0.126	-0.139
5a	-0.059	0.056
5b	0.299	0.163
5c	0.059	0.037
6a	0.044	0.115
6b	0.199	-0.033
6c	0.021	0.058
7a	0.004	0.073
7b	0.046	0.114
7c	0.098	0.083
8a	0.028	0.055
8b	-0.014	0.031
8c	-0.022	0.028
9a	-0.229	-0.074
9b	0.028	-0.053
9c	-0.075	-0.211

photo img_7188

2a	-0.008	0.284
2b	0.104	-0.268
2c	0.035	0.045
3a	0.006	0.053
3b	0.001	-0.083
3c	0.043	-0.078
4a	0.062	0.072
4b	0.061	0.053
4c	0.090	-0.022
5a	-0.118	0.163
5b	0.032	-0.163
5c	-0.152	-0.115
6a	0.034	-0.082
6b	0.010	-0.002
6c	-0.029	0.026
7a	-0.027	0.010
7b	-0.057	-0.062
7c	0.013	0.044
8a	0.084	-0.093
8b	0.047	-0.052
8c	0.088	-0.038
9a	-0.071	0.302
9b	0.074	-0.019
9c	0.070	0.032

photo img_7189

2a	-0.061	0.276
2b	0.085	-0.159
2c	0.041	0.021
3a	-0.016	0.026
3b	-0.049	-0.108
3c	-0.017	-0.175
4a	0.080	-0.016
4b	-0.036	-0.114
4c	0.101	-0.093
5a	0.014	0.170
5b	0.193	0.023

5c	0.034	-0.014
6a	-0.021	0.182
6b	-0.001	0.072
6c	-0.144	0.383
7a	-0.130	0.168
7b	-0.149	-0.022
7c	-0.072	0.016
8a	0.237	-0.104
8b	0.112	-0.016
8c	0.192	-0.106
9a	-0.060	-0.003
9b	0.156	-0.326
9c	-0.015	-0.041

post adjustment statistics & error propagation

rms-x,rms-y = 0.127 0.135
total coord rms = 0.130931
number of points = 27
number of control points = 3
number of observations = 450
number of photos = 9
redundancy = 324
post-adj sigma-nought squared = 0.02

exterior orientation data for photos

photo img_7181

w,p,k 0.953868 0.759299 0.446457
x,y,z 5.067 -2.869 2.839

photo img_7182

w,p,k 1.019264 0.741466 1.947818
x,y,z 5.101 -2.880 2.922

photo img_7183

w,p,k -0.912193 0.603686 2.706809
x,y,z 3.924 4.231 2.584

photo img_7184

w,p,k -0.793179 0.631253 -1.794621
x,y,z 3.973 4.250 2.656

photo img_7185

w,p,k -0.892121 -0.650327 -2.692126
x,y,z -2.091 4.119 2.641

photo img_7186

w,p,k -0.838319 -0.632458 -0.767815
x,y,z -2.589 4.449 3.008

photo img_7187

w,p,k 0.901738 -0.730722 -0.459962
x,y,z -2.705 -2.322 2.892

photo img_7188

```
w,p,k     0.754927    -0.586835     0.595177
x,y,z       -2.735        -2.326        2.916

photo img_7189

w,p,k     0.902685    -0.738290     0.720521
x,y,z       -2.708        -2.307        2.933

point coordinates

        1a        0.918       -0.913       -0.013
        1b        1.018       -0.815       -0.012
        1c        1.030       -0.940       -0.014
        2a        1.838       -0.000       -0.000
        2b        1.935        0.102        0.002
        2c        1.951       -0.023       -0.001
        3a        2.753        0.918       -0.012
        3b        2.855        1.015       -0.012
        3c        2.865        0.890       -0.013
        4a        0.000        0.000        0.000
        4b        0.100        0.099       -0.001
        4c        0.112       -0.026       -0.000
        5a        0.923        0.949        0.129
        5b        1.022        1.049        0.128
        5c        1.036        0.924        0.128
        6a        1.833        1.838        0.000
        6b        1.932        1.939        0.000
        6c        1.946        1.814       -0.000
        7a       -0.920        0.923        0.007
        7b       -0.813        1.014        0.006
        7c       -0.809        0.889        0.006
        8a        0.001        1.834        0.012
        8b        0.100        1.934        0.012
        8c        0.114        1.810        0.011
        9a        0.922        2.761        0.010
        9b        1.021        2.861        0.010
        9c        1.034        2.736        0.009

refined camera parameters

x0      -29.330
y0        1.519
foc     4457.796
k1  0.028382796
k2 -0.018956408
k3  0.011558139
p1   0.16170141
p2  -0.58011127
cond(N) before Wts  4.6490359e+14
cond(N) after Wts  1.0042308e+11


diary off
```