Photo1 HW4 Camera Calibration – due Wed 25th

- Take 3 photos with your camera at the designated camera stations. Zoom should be out. Center the lens over the point using a tripod. Measure the height of the lens over the point, add this to the Y station coordinate
- Measure image coordinates of the 25 designated targets (the target is the upper left corner of the brick). Point 1 is lower left, point 5 is lower right, point 6 second row up, on the left, point 25 is upper right, etc. Record points into separate files.
- Run suggested sequence with program pba2.m to estimate the focal length and lens distortion of your camera.
- Use prior HW results to get approximate focal length.
- More details coming.

```
 1  308  1948
 2 1085  1958
 3 1720  1961
 4 2431  1952
 5 3189  1934
 6  319  1693
 7 1090  1681
 8 1723  1668
 9 2430  1646
10 3179  1619
11  331  1442
12 1099  1406
13 1729  1374
14 2422  1339
15 3159  1304
16  346  1195
17 1108  1136
18 1728  1088
19 2412  1041
20 3143   995
21  369   882
22 1127   823
23 1734   764
24 2410   703
25 3122   648
```

three fields are: point number, sample (column), and line (row)
units of measurements should be pixels. the filename base should match the photo id given in file "pho.dat"

```
ph48
  0.150   0.280   0.000
  1.0e+10 1.0e+10 1.0e+10
  10.2748    1.8292   10.5552
  1.0e+10 1.0e+10 1.0e+10
ph50
  0.150   0.000   0.000
  1.0e+10 1.0e+10 1.0e+10
  6.7483     1.7683   12.1097
  1.0e+10 1.0e+10 1.0e+10
ph52
  0.150   -0.440   0.000
  1.0e+10 1.0e+10 1.0e+10
  2.0970     2.0500   10.5339
  1.0e+10 1.0e+10 1.0e+10
```

the record for each photo has:
photo ID
omega, phi, kappa (radians)
sigma-omega, sigma-phi, sigma-kappa
XL, YL, ZL
sigma-XL, sigma-YL, sigma-ZL

there should be one record for each photo in the block. to fix any of the parameters, edit the sigmas to be much smaller numbers. one arc second is 1 / 206264.8 radians.

```
0.0         0.001
0.0         0.001
4040        0.001
-0.26852739         0.0001
1.2105684           0.0001
-1.228008           0.0001
2
3684
2736
```

layout of the file is as follows:

x0	sigma-x0
y0	sigma-y0
f	sigma-f (units pixels)
k1	sigma-k1
k2	sigma-k2
k3	sigma-k3
2	(code for observations (s,l))
image width	(pixel units)
image height	(pixel units)

(edit the last two items to match your camera)

```
 1
    3.3528    2.0361    1.5240
    0.0001    0.0001    0.0001
 2
    5.6745    2.0376    1.5240
    0.0001    0.0001    0.0001
 3
    7.2965    2.0304    1.5240
    0.0001    0.0001    0.0001
 4
    8.9283    2.0305    1.5240
    0.0001    0.0001    0.0001
 5
   10.5581    2.0303    1.5240
    0.0001    0.0001    0.0001
 6
    3.3533    2.7144    1.5240
    0.0001    0.0001    0.0001
 7
    5.6748    2.7099    1.5240
    0.0001    0.0001    0.0001
 8
    7.3004    2.7039    1.5240
    0.0001    0.0001    0.0001
 9
    8.9379    2.7019    1.5240
    0.0001    0.0001    0.0001
10
   10.5618    2.6966    1.5240
    0.0001    0.0001    0.0001
11
    3.3534    3.3891    1.5240
    0.0001    0.0001    0.0001
12
    5.6816    3.3901    1.5240
    0.0001    0.0001    0.0001
13
    7.3119    3.3840    1.5240
    0.0001    0.0001    0.0001
14
    8.9348    3.3868    1.5240
    0.0001    0.0001    0.0001
15
   10.5564    3.3804    1.5240
    0.0001    0.0001    0.0001
16
    3.3519    4.0648    1.5240
    0.0001    0.0001    0.0001
17
    5.6852    4.0647    1.5240
    0.0001    0.0001    0.0001
18
    7.3088    4.0716    1.5240
    0.0001    0.0001    0.0001
19
    8.9318    4.0695    1.5240
    0.0001    0.0001    0.0001
20
   10.5589    4.0679    1.5240
    0.0001    0.0001    0.0001
21
    3.3532    4.9487    1.5240
    0.0001    0.0001    0.0001
22
    5.7028    4.8713    1.5240
    0.0001    0.0001    0.0001
23
    7.3197    4.8718    1.5240
    0.0001    0.0001    0.0001
24
    8.9519    4.8685    1.5240
    0.0001    0.0001    0.0001
25
   10.5682    4.8682    1.5240
    0.0001    0.0001    0.0001
```

control point file, format is,

point number
x y z
sigma-x, sigma-y, sigma-z
etc.

```
% collin.m  2-jan-03
% evaluate collinearity equation for given parameters
% note we are scaling the lens distortion coefficients
% for numerical stability

function F=collin(p)
x=p(1);
y=p(2);
x0=p(3);
y0=p(4);
foc=p(5);
k1=p(6);
k2=p(7);
k3=p(8);
w=p(9);
h=p(10);
k=p(11);
XL=p(12);
YL=p(13);
ZL=p(14);
X=p(15);
Y=p(16);
Z=p(17);

xp=x-x0;
yp=y-y0;
r=sqrt(xp^2 + yp^2);
% should eventually get this maximum radial distance
% from the camera definition, but hardwire for now
% this one for 3684 x 2736 digital camera
maxr=2300;
c1=1/(maxr^2);
c2=1/(maxr^4);
c3=1/(maxr^6);
% note: following gives problem for r=0
% dr=c1*k1*r^3 + c2*k2*r^5 + c3*k3*r^7;
% dx=dr*(xp/r);
% dy=dr*(yp/r);
% revise (equivalently) as
dr=c1*k1*r^2 + c2*k2*r^4 + c3*k3*r^6;
dx=dr*xp;
dy=dr*yp;

xpp=xp+dx;
ypp=yp+dy;
mw=[1 0 0;0 cos(w) sin(w);0 -sin(w) cos(w)];
mp=[cos(h) 0 -sin(h);0 1 0;sin(h) 0 cos(h)];
mk=[cos(k) sin(k) 0;-sin(k) cos(k) 0;0 0 1];
m=mk*mp*mw;
DX=[X-XL;Y-YL;Z-ZL];
UVW=m*DX;
Fx=xpp + foc*(UVW(1)/UVW(3));
Fy=ypp + foc*(UVW(2)/UVW(3));
F=[Fx;Fy];
```

edit maxr to be largest radial distance for your camera

```
ph48.dat
ph50.dat
ph52.dat
```

this is just a list of files containing image measurements. the filename base should match the photo ID in the file "pho.dat"

```
pba2
iter   1 position corrections:   0.002957   0.000886   0.002723
iter   2 position corrections:   0.000294   0.001072   0.001877
iter   3 position corrections:   0.000003   0.000005   0.000002
iter   4 position corrections:   0.000000   0.000000   0.000000
we have converged

observation residuals

photo ph48

         1      0.363     -1.067
         2     -4.860     -2.510
         3      1.799      4.458
         4      2.224     -1.409
         5     -1.974      1.043
         6      1.840     -0.189
         7     -2.365     -0.127
         8      2.291      6.559
         9     -1.728      1.199
        10      0.712     -1.843
        11      1.875     -0.854
        12     -0.451      1.925
        13      2.209     -0.903
        14     -3.825     -0.377
        15      3.893     -1.048
        16      0.760     -1.533
        17     -0.892      0.641
        18      2.385     -4.212
        19     -1.319     -1.094
        20      1.173     -0.530
        21      0.264     -0.663
        22     -5.110      2.271
        23      0.573     -1.186
        24      2.598      2.637
        25     -1.998     -1.556

photo ph50

         1      1.557     -1.768
         2     -1.004     -0.182
         3      1.143      5.241
         4      1.003     -1.482
         5     -0.471     -0.708
         6     -1.124     -0.385
         7      2.249      1.461
         8      0.232      5.901
         9     -1.358      0.246
        10      1.635     -1.741
        11     -0.816      0.425
        12      3.158      2.037
        13     -1.752     -2.278
        14     -3.128      0.578
        15      2.902     -1.378
        16     -0.963     -0.910
        17      1.914     -1.002
        18     -0.077     -4.790
        19     -2.266     -0.479
        20      1.461     -0.015
        21     -1.133      0.075
        22     -2.590      2.183
        23     -0.903     -2.572
        24      0.882      1.912
        25     -0.523     -0.654

photo ph52

         1      1.763     -1.991
         2     -0.059      0.827
         3     -0.580      1.042
         4      2.494     -4.904
         5     -3.480     -0.321
         6     -2.477     -2.177
         7      3.614      4.100
         8     -3.771      5.489
         9      2.841     -1.762
        10      0.116     -1.839
        11     -2.119      0.894
        12      6.108      2.613
        13     -6.849      1.292
        14      0.400      0.188
        15      2.485     -1.273
        16     -2.138     -0.071
```

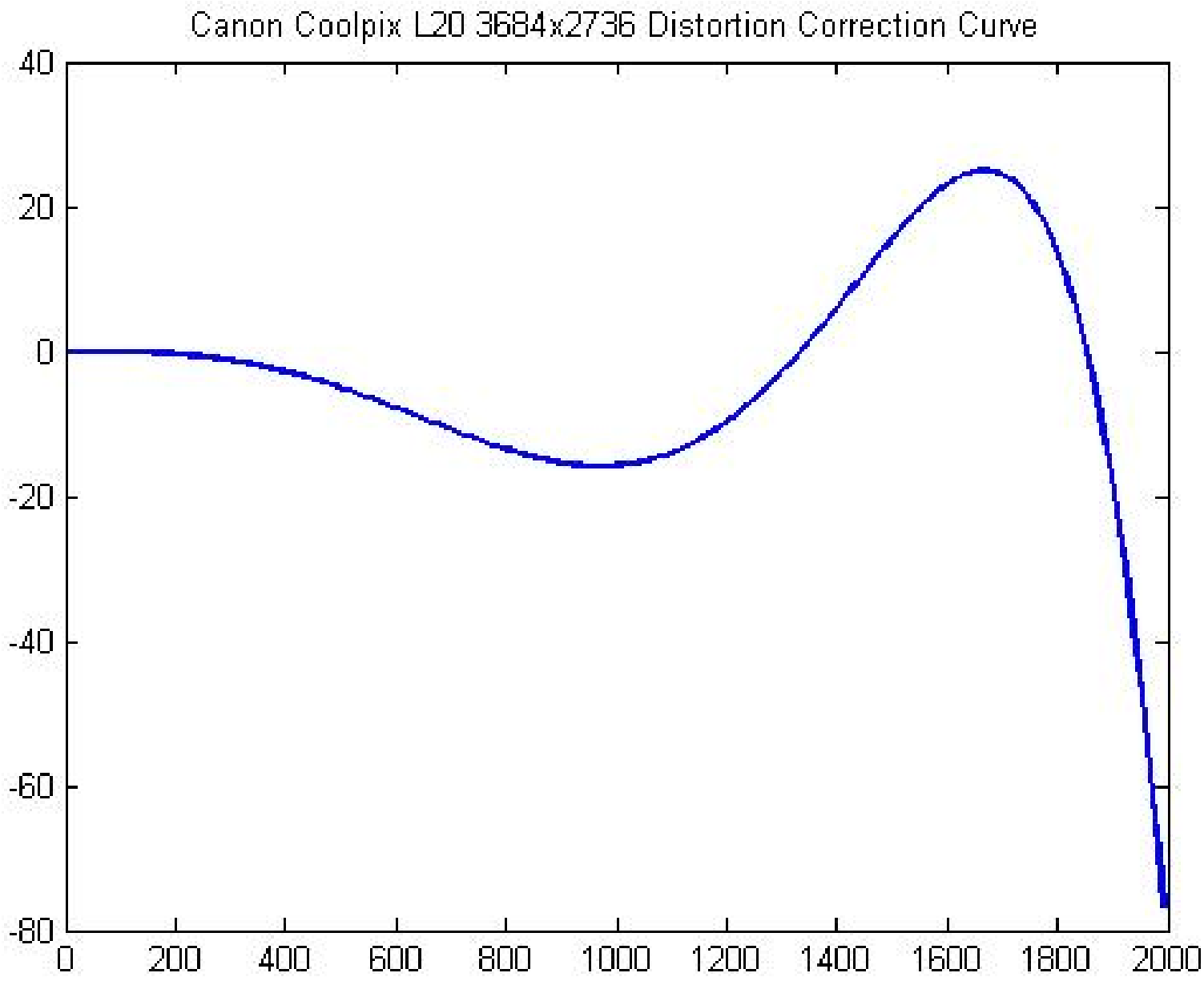
image residuals in pixels for x and y (sample and line)

```
        17      6.294     -3.339
        18     -6.377     -0.715
        19     -1.794      0.692
        20      0.789      0.889
        21      0.414      0.277
        22      2.449     -1.642
        23     -3.099     -1.653
        24      0.951      1.935
        25      1.661      1.432

post adjustment statistics & error propagation

rms-x,rms-y =       2.520      2.227
total coord rms =      2.378266
number of points =      25
number of control points =      25
number of observations =     150
number of photos =       3
redundancy =     132
post-adj sigma-nought squared =      1.61

exterior orientation data for photos

photo ph48

w,p,k     0.169718     0.286114    -0.050002
x,y,z       10.282        1.840       10.552

photo ph50

w,p,k     0.143272    -0.044776     0.010394
x,y,z        6.749        1.784       12.131

photo ph52

w,p,k     0.168182    -0.441734     0.068890
x,y,z        2.180        2.062       10.583

point coordinates

         1        3.353        2.036        1.524
         2        5.675        2.038        1.524
         3        7.296        2.030        1.524
         4        8.928        2.031        1.524
         5       10.558        2.030        1.524
         6        3.353        2.714        1.524
         7        5.675        2.710        1.524
         8        7.300        2.704        1.524
         9        8.938        2.702        1.524
        10       10.562        2.697        1.524
        11        3.353        3.389        1.524
        12        5.682        3.390        1.524
        13        7.312        3.384        1.524
        14        8.935        3.387        1.524
        15       10.556        3.380        1.524
        16        3.352        4.065        1.524
        17        5.685        4.065        1.524
        18        7.309        4.072        1.524
        19        8.932        4.070        1.524
        20       10.559        4.068        1.524
        21        3.353        4.949        1.524
        22        5.703        4.871        1.524
        23        7.320        4.872        1.524
        24        8.952        4.868        1.524
        25       10.568        4.868        1.524

refined camera parameters

x0       -0.000
y0        0.000
foc     4040.000
k1  -0.26851241
k2    1.2105713
k3   -1.2280079
cond(N) before Wts 5.6443109e+019
cond(N) after Wts      194090.77


diary off
```

root mean square for x & y

for each photo: omega, phi, kappa (rad), then XL, YL, ZL

estimated values for the inner orientation parameters, also condition numbers


Canon Coolpix L20 3684x2736 Distortion Correction Curve
40
20
0
-20
-40
-60
-80
0
200
400
600
800
1000
1200
1400
1600
1800
2000

files needed to run pba2 - photogrammetric block adjustment

pba2.m
collin.m (set "maxr" to be max radial distance for your camera)
gencof.m
gndx.m
int_leq.m

data files needed

cam.dat   - parameters of the camera & image
cp.dat   - control points
pho.dat   - XL,YL,ZL,omega,phi,kappa + sigma for all images
phofiles.dat   - list of the image measurement files
  *.dat   - 3 image measurement files (# sample line)
  *.dat
  *.dat
sig.dat   - sigmas for the adjustment

steps for camera calibration

0. add your "HI's" to the Y-coordinate (below) and
   enter into "pho.dat" file

1. fix XL,YL,ZL - sigma = 1.oe-05
   free omega, phi, kappa - sigma = 1.oe+08
   these are in "pho.dat"

2. fix all camera internal parameters ("cam.dat")
   at nominal values
   x0=0,y0=0,f=your f (pixel units) - sigma = 0.001
   fix lens distortion coefficients
   k1,k2,k3 = 0, sigma = 0.001

3. run & debug your measurements (rmsx,y < 15 pixels)

4. free focal length, sigma = 5% of value

5. fix f at new estimated value - sigma = 0.001

6. free k1,k2,k3 - sigma = 200

7. fix k1,k2,k3 at estimated values - sigma = 0.001

8. free XL,YL,ZL, should have rmsx,y < 2 pixels

* record rmsx,y after each step
* turn in full listing for last step
* we are leaving x0,y0 at nominal value (center of image)

edit image width and image height to match your camera. leave code number at 2.

P1 (near wall) 10.2748 1.3152 10.5552
P2   6.7483 1.2543 12.1097
P3 (bike path)   2.0970 1.0000 10.5339

remember to add your HI to the Y-coordinate of P1,P2, and P3. all length units and coordinates are meters.