```
sph01
np =
    341
n =
       1023
u =
     4
n0 =
    686
r =
    337
c =
    341
keep_going =
     1
iter =
     1
ans =
  Columns 1 through 3
       0.00375729684859144       -0.0159687429771286        0.0101736827247065
  Column 4
      -0.0276730388451996
iter =
     2
ans =
  Columns 1 through 3
      -0.000365746146370232     8.72845926982607e-05     -9.41655491024595e-05
  Column 4
       0.000314721675637149
iter =
     3
ans =
  Columns 1 through 3
      -6.80321876722892e-07     -2.69856687137089e-06      8.28905520374631e-07
  Column 4
      -1.28339115607957e-06
iter =
     4
ans =
  Columns 1 through 3
      -5.67214488999497e-08      1.51086894033576e-08     -4.8672242006541e-09
  Column 4
      -2.7268248810915e-08
iter =
     5
ans =
  Columns 1 through 3
      -1.80250233365697e-10     -1.64591037108114e-09      3.15178651518561e-10
  Column 4
      -7.42040268208472e-10
we have converged
p =
       3.05339081347865
       1.91411585651148
      -0.539919658470921
       0.272640371428992
vTv =
      0.000631268534497871
sig0sqr_hat =
       1.87320039910347e-06
TS =
      25.2507413799148
cv1 =
      288.036334648026
cv2 =
      389.750657067005
cov_xz =
       8.47999609186644e-08     -1.19661495428317e-08
      -1.19661495428317e-08      2.65298662957026e-08
cov_yz =
       4.7087588177851e-08      -7.15667686634169e-09
      -7.15667686634168e-09      2.65298662957026e-08
vec =
       0.981075980706585
      -0.193623139321242
vec2 =
       0.193623139321242
       0.981075980706585
a =
      0.000635727132686265
b =
      0.000334757894860966
theta =
      -0.194853836285083
thetad =
      -11.1643024410683
vec =
       0.954115923426774
      -0.299437480391942
vec2 =
       0.299437480391942
```

```
          0.954115923426774
a =
       0.000478277240919799
b =
       0.000335557398853812
theta =
         -0.304103027872592
thetad =
           -17.4238200342487
diary off
```

```
% sph01.m  4-dec-2013

% update the observations
% LS fit of sphere to point cloud
% batch solution


degrad=180/pi;
xc=3.05;
yc=1.93;
zc=-0.55;
R=0.30;
p=[xc;yc;zc;R];
% summary stats
vTv=0.0;
sumvxsqr=0;
sumvysqr=0;
sumvzsqr=0;
maxvx=0;
maxvy=0;
maxvz=0;
load sphere_m.xyz
% XYZ original observations
X=sphere_m(:,1);
Y=sphere_m(:,2);
Z=sphere_m(:,3);
[np,nn]=size(X);
% X0Y0Z0 updated observations
X0=X;
Y0=Y;
Z0=Z;
np
n=np*3
u=4
n0=u + np*2
r=n-n0
sigi=0.005; % 1 mm
sig0=0.005;
% W,Q=identity so we leave it out of the solution
c=r+u
A=zeros(c,n);
B=zeros(c,u);
f=zeros(c,1);

keep_going=1
iter=0;
while(keep_going == 1)
  iter=iter+1
  % get current parameters from the parameter vector
  xc=p(1);
  yc=p(2);
  zc=p(3);
  R=p(4);

  for i=1:np
    % c is also equal to np so we use i for row counter
    XX=X0(i);
    YY=Y0(i);
    ZZ=Z0(i);
    F=R - sqrt((XX-xc)^2 + (YY-yc)^2 + (ZZ-zc)^2);
    d=sqrt((XX-xc)^2 + (YY-yc)^2 + (ZZ-zc)^2);
    dFdX=-(XX-xc)/d;
    dFdY=-(YY-yc)/d;
    dFdZ=-(ZZ-zc)/d;
    dFdxc=-dFdX;
    dFdyc=-dFdY;
    dFdzc=-dFdZ;
    dFdR=1;
    j=(i-1)*3 + 1;
    A(i,j:j+2)=[dFdX dFdY dFdZ];
    B(i,:)=[dFdxc dFdyc dFdzc dFdR];
    f(i)=-F - A(i,j:j+2)*[X(i)-XX;Y(i)-YY;Z(i)-ZZ];
    end
  Qe=A*A';
  We=inv(Qe);
  N=B'*We*B;
  t=B'*We*f;
  del=inv(N)*t;
  del'
  k=We*(f-B*del);
  v=A'*k;
  for i=1:np
    idx=(i-1)*3 + 1;
    X0(i)=X(i) + v(idx);
    Y0(i)=Y(i) + v(idx+1);
    Z0(i)=Z(i) + v(idx+2);
    end

  p=p+del;
  if((all(abs(del) < 1e-08)) && (iter < 10))
    disp('we have converged');
```

```
      keep_going=0;
    else
      if(iter >= 10)
        keep_going=0;
        end
      end
    end
  end % while(keep_going==1)

p
vTv=v'*v
sig0sqr_hat=vTv/r
TS=vTv/sig0^2
alpha=0.05;
cv1=icdf('chi2',alpha/2,r)
cv2=icdf('chi2',1-alpha/2,r)
Qdd=inv(N);
Sdd=sig0sqr_hat*Qdd;
cov_xz=[Sdd(1,1) Sdd(1,3); Sdd(3,1) Sdd(3,3)]
cov_yz=[Sdd(2,2) Sdd(2,3); Sdd(3,2) Sdd(3,3)]
plot_conf_ell(cov_xz,0,r,0.90,xc,zc,1.0);
title('XZ 90% conf. ellipse');
axis equal
figure(2)
plot_conf_ell(cov_yz,0,r,0.90,yc,zc,1.0);
title('YZ 90% conf. ellipse');
axis equal
```

XZ 90% conf. ellipse
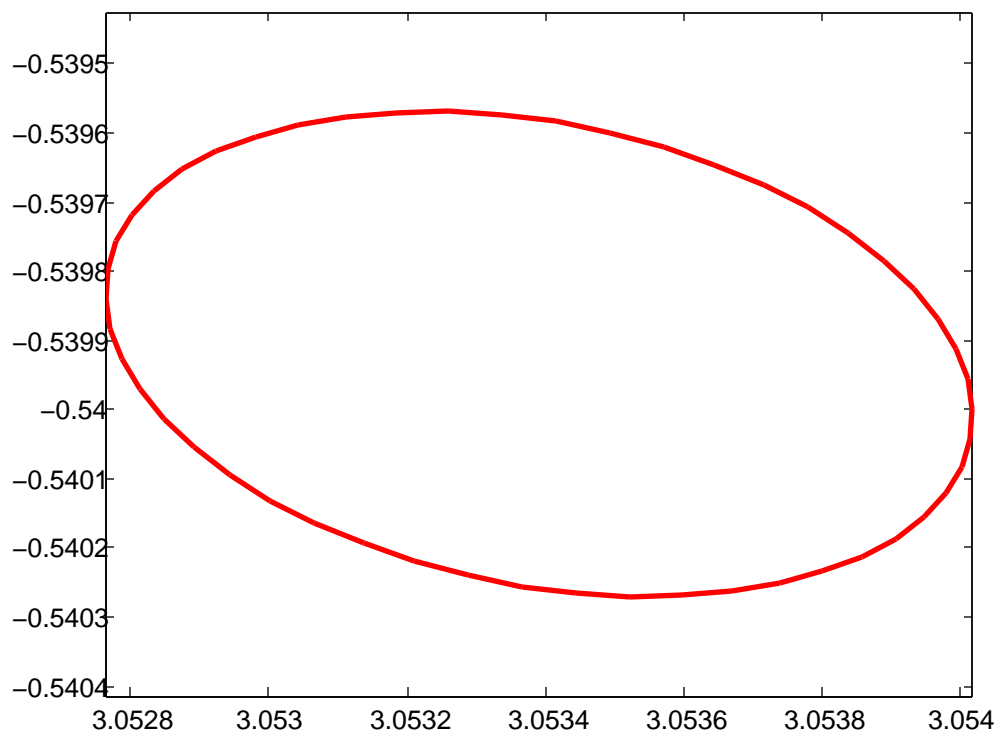
YZ 90% conf. ellipse
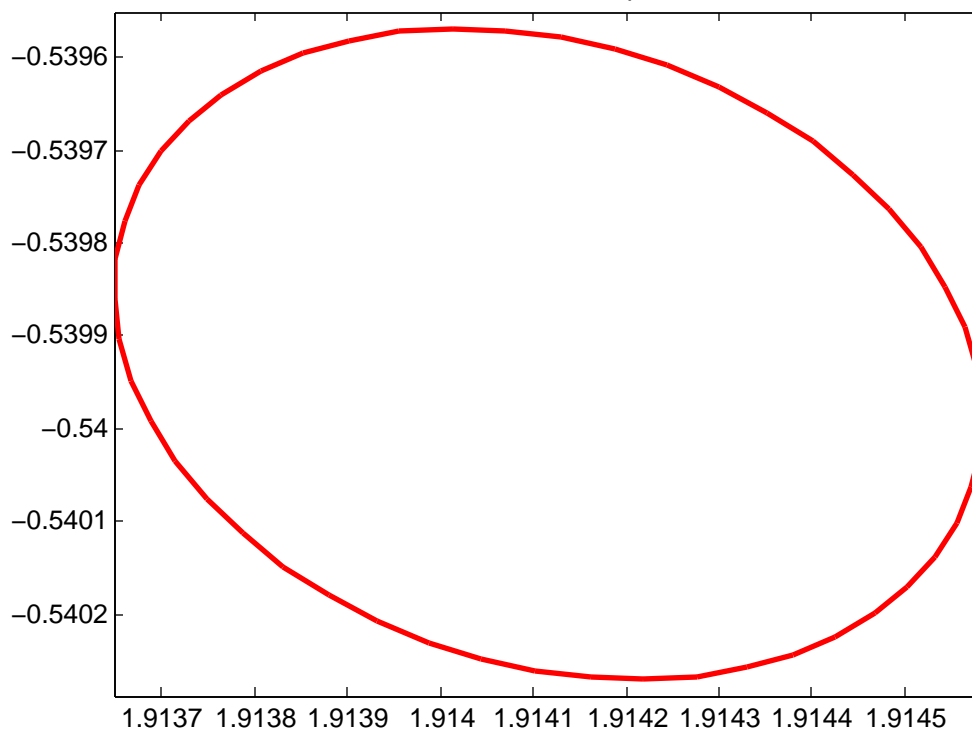
```
par7
np =
     5
n =
    30
n0 =
    22
r =
     8
u =
     7
c =
    15
keep_going =
     1
iter =
     1
del =
        0.0804044117647059
        0.0610775862068966
         0.104017857142857
                   0.19345
        0.0452518907563025
        0.0350402129817446
        0.0149543972761519
iter =
     2
del =
        0.0162517837416517
       -0.0100162922809297
      -0.00447064206642834
       -0.0194416377267072
       0.00129893508795582
      -0.00877566736778424
       -0.0313947970957667
iter =
     3
del =
       0.00020933881768169
      0.000170187135229218
      0.000414920367784622
        0.0002478528023143
      0.000158310370835561
      1.74806621536016e-05
       -0.0007921828719581
iter =
     4
del =
       1.71878536131082e-06
       4.93194807351527e-08
      -3.65480824089342e-06
      -1.84925671106535e-06
      -1.47665339127639e-06
      -8.87469377536258e-06
       6.83989953303789e-06
iter =
     5
del =
       2.16638759539708e-08
       1.17808153258994e-08
       8.83678929655387e-08
       2.14493578151356e-08
       -5.8519501312886e-08
      -1.56533161879667e-08
      -1.63572578424246e-07
iter =
     6
del =
       1.74454535799197e-10
      -4.22210910587505e-11
      -6.82690731126361e-10
      -1.60870430845235e-10
      -4.16139276272291e-10
      -7.90524597926579e-10
       1.20523032159962e-09
we have converged
p =
          1.09686727494773
         0.0512315421192711
         0.0999585683211749
          0.174254387107383
          0.046707600626062
         0.0262731351384978
        -0.0172259051593879
vTv =
         0.00607860449405709
sig0sqr_hat =
        0.000759825561757137
TS =
          6.75400499339677
cv1 =
```

```
        2.17973074725265
cv2 =
        17.5345461394846
half_intvl =
        0.0140446015754115
90% conf intvl scale
ans =
        1.08282267319787              1.11091187634869
diary off
```

```
% par7.m  4-dec-2013
% hw5 for data1

X=[1;3;3;1;2];
Y=[1;1;5;5;3];
Z=[0;0;0;0;3];
x=[1.275;3.493;4.203;2.147;2.502];
y=[0.930;0.561;4.866;5.202;3.071];
z=[0.013;0.282;0.017;-0.213;3.341];
X0=X;
Y0=Y;
Z0=Z;
x0=x;
y0=y;
z0=z;

% initial approx
lam=1.0;
om=0.0;
ph=0.0;
kp=0.0;
tx=0.0;
ty=0.0;
tz=0.0;
p=[lam;om;ph;kp;tx;ty;tz];

np=5
n=np*3*2
n0=7+np*3
r=n-n0
u=7
c=r+u
sig=0.03;
sig0=0.03;
% so W=Q=I so we leave it out of expressions

keep_going=1
iter=0;
while(keep_going == 1)
  iter=iter+1
  A=zeros(c,n);
  B=zeros(c,u);
  f=zeros(c,1);
  rowc=1;
  colc=1;
  % extract values from param vector
  lam=p(1);
  om=p(2);
  ph=p(3);
  kp=p(4);
  tx=p(5);
  ty=p(6);
  tz=p(7);
  mw=m1(om);
  mp=m2(ph);
  mk=m3(kp);
  m=mk*mp*mw;

  for i=1:np
    XYZ=[X0(i);Y0(i);Z0(i)];
    xyz=[x0(i);y0(i);z0(i)];
    Ai=[eye(3) -lam*m];
    dFdlam=-m*XYZ;
    dFdw=-lam*mk*mp*[0 0 0;0 -sin(om) cos(om);0 -cos(om) -sin(om)]*XYZ;
    dFdp=-lam*mk*[-sin(ph) 0 -cos(ph);0 0 0;cos(ph) 0 -sin(ph)]*mw*XYZ;
    dFdk=-lam*[-sin(kp) cos(kp) 0;-cos(kp) -sin(kp) 0;0 0 0]*mp*mw*XYZ;
    dFdt=-eye(3);
    Bi=[dFdlam dFdw dFdp dFdk dFdt];
    F=xyz - lam*m*XYZ - [tx;ty;tz];
    fi=-F - Ai*[x(i)-x0(i);y(i)-y0(i);z(i)-z0(i);X(i)-X0(i);Y(i)-Y0(i);Z(i)-Z0(i)];
    A(rowc:rowc+2,colc:colc+5)=Ai;
    B(rowc:rowc+2,:)=Bi;
    f(rowc:rowc+2)=fi;
    rowc=rowc+3;
    colc=colc+6;
    end
  Qe=A*A';
  We=inv(Qe);
  N=B'*We*B;
  t=B'*We*f;
  del=inv(N)*t
  p=p+del;
  k=We*(f-B*del);
  v=A'*k;
  for i=1:np
    idx=(i-1)*6 + 1;
    x0(i)=x(i) + v(idx);
    y0(i)=y(i) + v(idx+1);
    z0(i)=z(i) + v(idx+2);
    X0(i)=X(i) + v(idx+3);
    Y0(i)=Y(i) + v(idx+4);
```

```
  Z0(i)=Z(i) + v(idx+5);
    end

  if((all(abs(del) < 1e-08)) && (iter < 10))
    disp('we have converged');
    keep_going=0;
  else
    if(iter >= 10)
      keep_going=0;
      disp('bailing out - no convergence');
    end
  end
  end % while(keep_going==1)

p
vTv=v'*v
sig0sqr_hat=vTv/r
TS=vTv/sig0^2
alpha=0.05;
cv1=icdf('chi2',alpha/2,r)
cv2=icdf('chi2',1-alpha/2,r)
% pass !
Qdd=inv(N);
Sdd=sig0^2*Qdd;

P=0.90;
s=sqrt(Sdd(1,1));
z=icdf('norm',(P+1)/2,0,1);
half_intvl=z*s
disp('90% conf intvl scale');
[lam-half_intvl lam+half_intvl]
```