HW2

Problem 1:

A.

```
function [U, S, V] = mysvd(A)

n = size(A, 1);
p = size(A, 2);
[V, L] = jacobi(A' * A);
L = diag(L);

%sort V, L simultaneously
for i=1:p
max = i; %index of current max eigenvalue
    for j=i+1:p
        if (L(j) > L(i))
            max = j;
        end
    end
    if max ~= i %swap columns
        tmp_L = L(i);
        L(i) = L(max);
        L(max) = tmp_L;
        tmp_V = V(:,i);
        V(:,i) = V(:,max);
        V(:,max) = tmp_V;
    end
end
S = sqrt(diag(L));
if p > n
    S = S(1:n, 1:p);
else
    S = [S; zeros(p-n, p)];
end
U = A * V * mypinv(S);

%------------------------------
function Sminus = mypinv(S)

m = size(S, 1);
n = size(S, 2);
Sminus = zeros(n, m);
p = min(m, n);
for i = 1:p
    if S(i,i) ~= 0
        Sminus(i,i) = 1/S(i,i);
    end

end

%Testing: ------------------------------
C = gallery('chow', 8);
F = hadamard(8);
H = hilb(8);
P = pascal(8);
```

```
[U, S, V] = mysvd(C)

U =

  Columns 1 through 6

   0.1491 + 0.0000i  -0.3899 + 0.0000i  -0.5050 + 0.0000i   0.5073 + 0.0000i   0.4341 + 0.0000i
0.3133 + 0.0000i
   0.2195 + 0.0000i  -0.4824 + 0.0000i  -0.3681 + 0.0000i  -0.0134 + 0.0000i  -0.3917 + 0.0000i
-0.5379 + 0.0000i
   0.2839 + 0.0000i  -0.4483 + 0.0000i   0.0527 + 0.0000i  -0.5137 + 0.0000i  -0.2766 + 0.0000i
0.3415 + 0.0000i
   0.3405 + 0.0000i  -0.2964 + 0.0000i   0.4329 + 0.0000i  -0.2298 + 0.0000i   0.5029 + 0.0000i
0.1222 + 0.0000i
   0.3876 + 0.0000i  -0.0667 + 0.0000i   0.4792 + 0.0000i   0.4049 + 0.0000i   0.0743 + 0.0000i
-0.4903 + 0.0000i
   0.4241 + 0.0000i   0.1806 + 0.0000i   0.1560 + 0.0000i   0.4215 + 0.0000i  -0.5328 + 0.0000i
0.4746 + 0.0000i
   0.4489 + 0.0000i   0.3804 + 0.0000i  -0.2875 + 0.0000i  -0.2053 + 0.0000i   0.1401 + 0.0000i
-0.0873 + 0.0000i
   0.4489 + 0.0000i   0.3804 + 0.0000i  -0.2875 + 0.0000i  -0.2053 + 0.0000i   0.1401 + 0.0000i
-0.0873 + 0.0000i

  Columns 7 through 8

  -0.1635 + 0.0000i   0.0000 + 2.1500i
   0.3749 + 0.0000i   0.0000 + 0.9389i
  -0.5086 + 0.0000i   0.0000 + 1.9009i
   0.5368 + 0.0000i   0.0000 + 1.1321i
  -0.4537 + 0.0000i   0.0000 + 0.9270i
   0.2765 + 0.0000i   0.0000 + 0.1855i
  -0.0420 + 0.0000i   0.0000 + 0.1914i
  -0.0420 + 0.0000i   0.0000 + 0.1914i


S =

  Columns 1 through 6

   6.0208 + 0.0000i   0.0000 + 0.0000i   0.0000 + 0.0000i   0.0000 + 0.0000i   0.0000 + 0.0000i
0.0000 + 0.0000i
   0.0000 + 0.0000i   1.9513 + 0.0000i   0.0000 + 0.0000i   0.0000 + 0.0000i   0.0000 + 0.0000i
0.0000 + 0.0000i
   0.0000 + 0.0000i   0.0000 + 0.0000i   1.1387 + 0.0000i   0.0000 + 0.0000i   0.0000 + 0.0000i
0.0000 + 0.0000i
   0.0000 + 0.0000i   0.0000 + 0.0000i   0.0000 + 0.0000i   0.8094 + 0.0000i   0.0000 + 0.0000i
0.0000 + 0.0000i
   0.0000 + 0.0000i   0.0000 + 0.0000i   0.0000 + 0.0000i   0.0000 + 0.0000i   0.6452 + 0.0000i
0.0000 + 0.0000i
   0.0000 + 0.0000i   0.0000 + 0.0000i   0.0000 + 0.0000i   0.0000 + 0.0000i   0.0000 + 0.0000i
0.5575 + 0.0000i
   0.0000 + 0.0000i   0.0000 + 0.0000i   0.0000 + 0.0000i   0.0000 + 0.0000i   0.0000 + 0.0000i
0.0000 + 0.0000i
   0.0000 + 0.0000i   0.0000 + 0.0000i   0.0000 + 0.0000i   0.0000 + 0.0000i   0.0000 + 0.0000i
0.0000 + 0.0000i

  Columns 7 through 8

   0.0000 + 0.0000i   0.0000 + 0.0000i
   0.0000 + 0.0000i   0.0000 + 0.0000i
   0.0000 + 0.0000i   0.0000 + 0.0000i
   0.0000 + 0.0000i   0.0000 + 0.0000i
   0.0000 + 0.0000i   0.0000 + 0.0000i
   0.0000 + 0.0000i   0.0000 + 0.0000i
   0.5135 + 0.0000i   0.0000 + 0.0000i
   0.0000 + 0.0000i   0.0000 + 0.0000i


V =
```

```
    0.4489   -0.3804   -0.2875    0.2053    0.1401    0.0873   -0.0420    0.7071
    0.4489   -0.3804   -0.2875    0.2053    0.1401    0.0873   -0.0420   -0.7071
    0.4241   -0.1806    0.1560   -0.4215   -0.5328   -0.4746    0.2765    0.0000
    0.3876    0.0667    0.4792   -0.4049    0.0743    0.4903   -0.4537   -0.0000
    0.3405    0.2964    0.4329    0.2298    0.5029   -0.1222    0.5368    0.0000
    0.2839    0.4483    0.0527    0.5137   -0.2766   -0.3415   -0.5086    0.0000
    0.2195    0.4824   -0.3681    0.0134   -0.3917    0.5379    0.3749    0.0000
    0.1491    0.3899   -0.5050   -0.5073    0.4341   -0.3133   -0.1635   -0.0000

[U, S, V] = mysvd(F)

U =

  0.3536   0.3536   0.3536   0.3536   0.3536   0.3536   0.3536   0.3536
  0.3536  -0.3536   0.3536  -0.3536   0.3536  -0.3536   0.3536  -0.3536
  0.3536   0.3536  -0.3536  -0.3536   0.3536   0.3536  -0.3536  -0.3536
  0.3536  -0.3536  -0.3536   0.3536   0.3536  -0.3536  -0.3536   0.3536
  0.3536   0.3536   0.3536   0.3536  -0.3536  -0.3536  -0.3536  -0.3536
  0.3536  -0.3536   0.3536  -0.3536  -0.3536   0.3536  -0.3536   0.3536
  0.3536   0.3536  -0.3536  -0.3536  -0.3536  -0.3536   0.3536   0.3536
  0.3536  -0.3536  -0.3536   0.3536  -0.3536   0.3536   0.3536  -0.3536


S =

  2.8284       0       0       0       0       0       0       0
       0  2.8284       0       0       0       0       0       0
       0       0  2.8284       0       0       0       0       0
       0       0       0  2.8284       0       0       0       0
       0       0       0       0  2.8284       0       0       0
       0       0       0       0       0  2.8284       0       0
       0       0       0       0       0       0  2.8284       0
       0       0       0       0       0       0       0  2.8284


V =

  1   0   0   0   0   0   0   0
  0   1   0   0   0   0   0   0
  0   0   1   0   0   0   0   0
  0   0   0   1   0   0   0   0
  0   0   0   0   1   0   0   0
  0   0   0   0   0   1   0   0
  0   0   0   0   0   0   1   0
  0   0   0   0   0   0   0   1

[U, S, V] = mysvd(H)
U =

 Columns 1 through 6

  0.7203 + 0.0000i  -0.6295 + 0.0000i   0.2775 + 0.0000i   0.0865 + 0.0000i   0.0207 + 0.0000i   0.0038 + 0.0000i
  0.4325 + 0.0000i   0.1257 + 0.0000i  -0.6449 + 0.0000i  -0.5501 + 0.0000i  -0.2661 + 0.0000i  -0.0858 + 0.0000i
  0.3188 + 0.0000i   0.2864 + 0.0000i  -0.3352 + 0.0000i   0.3363 + 0.0000i   0.6241 + 0.0000i   0.4188 + 0.0000i
  0.2552 + 0.0000i   0.3276 + 0.0000i  -0.0513 + 0.0000i   0.4592 + 0.0000i  -0.0320 + 0.0000i  -0.5797 + 0.0000i
  0.2139 + 0.0000i   0.3321 + 0.0000i   0.1440 + 0.0000i   0.2756 + 0.0000i  -0.4194 + 0.0000i  -0.1232 + 0.0000i
  0.1845 + 0.0000i   0.3235 + 0.0000i   0.2729 + 0.0000i   0.0113 + 0.0000i  -0.3655 + 0.0000i   0.4185 + 0.0000i
  0.1625 + 0.0000i   0.3103 + 0.0000i   0.3570 + 0.0000i  -0.2490 + 0.0000i  -0.0180 + 0.0000i   0.3524 + 0.0000i
  0.1453 + 0.0000i   0.2956 + 0.0000i   0.4116 + 0.0000i  -0.4773 + 0.0000i   0.4780 + 0.0000i  -0.4083 + 0.0000i

 Columns 7 through 8

  0.0006 + 0.0000i   0.0000 - 0.0005i
 -0.0199 + 0.0000i   0.0000 + 0.0173i
  0.1676 + 0.0000i   0.0000 - 0.1454i
 -0.5264 + 0.0000i   0.0000 + 0.4552i
  0.6052 + 0.0000i   0.0000 - 0.5156i
```

```
  0.0778 + 0.0000i   0.0000 - 0.0916i
 -0.6072 + 0.0000i   0.0000 + 0.5527i
  0.3027 + 0.0000i   0.0000 - 0.2726i


S =

  Columns 1 through 6

  1.6959 + 0.0000i   0.0000 + 0.0000i   0.0000 + 0.0000i   0.0000 + 0.0000i   0.0000 + 0.0000i   0.0000 + 0.0000i
  0.0000 + 0.0000i   0.2981 + 0.0000i   0.0000 + 0.0000i   0.0000 + 0.0000i   0.0000 + 0.0000i   0.0000 + 0.0000i
  0.0000 + 0.0000i   0.0000 + 0.0000i   0.0262 + 0.0000i   0.0000 + 0.0000i   0.0000 + 0.0000i   0.0000 + 0.0000i
  0.0000 + 0.0000i   0.0000 + 0.0000i   0.0000 + 0.0000i   0.0015 + 0.0000i   0.0000 + 0.0000i   0.0000 + 0.0000i
  0.0000 + 0.0000i   0.0000 + 0.0000i   0.0000 + 0.0000i   0.0000 + 0.0000i   0.0001 + 0.0000i   0.0000 + 0.0000i
  0.0000 + 0.0000i   0.0000 + 0.0000i   0.0000 + 0.0000i   0.0000 + 0.0000i   0.0000 + 0.0000i   0.0000 + 0.0000i
  0.0000 + 0.0000i   0.0000 + 0.0000i   0.0000 + 0.0000i   0.0000 + 0.0000i   0.0000 + 0.0000i   0.0000 + 0.0000i
  0.0000 + 0.0000i   0.0000 + 0.0000i   0.0000 + 0.0000i   0.0000 + 0.0000i   0.0000 + 0.0000i   0.0000 + 0.0000i

  Columns 7 through 8

  0.0000 + 0.0000i   0.0000 + 0.0000i
  0.0000 + 0.0000i   0.0000 + 0.0000i
  0.0000 + 0.0000i   0.0000 + 0.0000i
  0.0000 + 0.0000i   0.0000 + 0.0000i
  0.0000 + 0.0000i   0.0000 + 0.0000i
  0.0000 + 0.0000i   0.0000 + 0.0000i
  0.0000 + 0.0000i   0.0000 + 0.0000i
  0.0000 + 0.0000i   0.0000 + 0.0000i


V =

   0.7203   -0.6295    0.2775    0.0865    0.0207    0.0038    0.0005    0.0000
   0.4325    0.1257   -0.6449   -0.5501   -0.2661   -0.0858   -0.0190   -0.0006
   0.3188    0.2864   -0.3352    0.3363    0.6241    0.4188    0.1613   -0.0065
   0.2552    0.3276   -0.0513    0.4592   -0.0320   -0.5797   -0.5175    0.0953
   0.2139    0.3321    0.1440    0.2756   -0.4194   -0.1232    0.6391   -0.3843
   0.1845    0.3235    0.2729    0.0113   -0.3655    0.4185   -0.0404    0.6901
   0.1625    0.3103    0.3570   -0.2490   -0.0180    0.3523   -0.4797   -0.5773
   0.1453    0.2956    0.4116   -0.4773    0.4780   -0.4083    0.2560    0.1833

[U, S, V] = mysvd(P)
U =

   0.0004   -0.0101   -0.1115    0.5279    0.7379    0.3852    0.1234   -0.0246
   0.0026   -0.0469   -0.2879    0.5622   -0.0478   -0.6097   -0.4490    0.1523
   0.0110   -0.1313   -0.4686    0.3041   -0.4085    0.0148    0.5796   -0.4093
   0.0345   -0.2747   -0.5254   -0.1083   -0.1928    0.4431   -0.1412    0.6181
   0.0909   -0.4554   -0.3298   -0.3584    0.2497   -0.0005   -0.4067   -0.5650
   0.2107   -0.5801    0.1203   -0.1490    0.2768   -0.4362    0.4669    0.3122
   0.4434   -0.4285    0.4886    0.3698   -0.3213    0.2984   -0.2066   -0.0965
   0.8657    0.4213   -0.2171   -0.1170    0.0837   -0.0628    0.0345    0.0128


S =

  1.0e+03 *

   4.5437         0         0         0         0         0         0         0
        0    0.1488         0         0         0         0         0         0
        0         0    0.0119         0         0         0         0         0
        0         0         0    0.0020         0         0         0         0
        0         0         0         0    0.0005         0         0         0
        0         0         0         0         0    0.0001         0         0
        0         0         0         0         0         0    0.0000         0
        0         0         0         0         0         0         0    0.0000
```

V =

0.0004	-0.0101	-0.1115	0.5279	0.7379	0.3852	0.1234	-0.0246
0.0026	-0.0469	-0.2879	0.5622	-0.0478	-0.6097	-0.4490	0.1523
0.0110	-0.1313	-0.4686	0.3041	-0.4085	0.0148	0.5796	-0.4094
0.0345	-0.2747	-0.5254	-0.1083	-0.1928	0.4431	-0.1412	0.6182
0.0909	-0.4554	-0.3298	-0.3584	0.2497	-0.0005	-0.4067	-0.5651
0.2107	-0.5801	0.1203	-0.1490	0.2768	-0.4362	0.4669	0.3123
0.4434	-0.4285	0.4886	0.3698	-0.3213	0.2984	-0.2066	-0.0965
0.8657	0.4213	-0.2171	-0.1170	0.0837	-0.0628	0.0345	0.0128

B.

Using the singular values in the S matrices printed above, here are the conditional numbers of each matrix:

Chow: 6.0208 / 0.6452 = 9.33
Hadamard: 2.8284/2.8284 = 1
Hilbert: 1.6959/0.0001 = 16959
Pascal: 4.5437 / 0.0001 = 45437

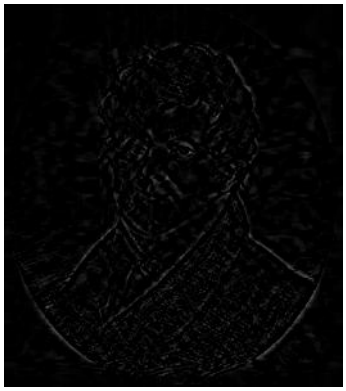
C.

```
A = double(imread('Joseph_Fourier_1820.jpg'))/255;
R = A(:,:,1);
G = A(:,:,2);
B = A(:,:,3);
A = (R+G+B)/3;
```

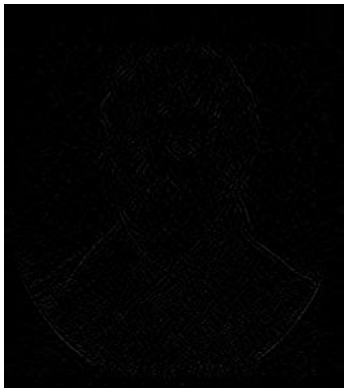
```
[U, S, V] = mysvd(A);
S(1:5, 1:5) = 0;
Serror5 = S;
Aerror5 = U*Serror5*V';
imshow(Aerror5);
```

```
S(1:10, 1:10) = 0;
Serror10 = S;
Aerror10 = U*Serror10*V';
imshow(Aerror10);
```

```
S(1:20, 1:20) = 0;
Serror20 = S;
Aerror20 = U*Serror20*V';
imshow(Aerror20);
```



```
S(1:50, 1:50) = 0;
Serror50 = S;
Aerror50 = U*Serror50*V';
imshow(Aerror50);
```



Problem 2:

A.

```
function r = quaternionmultiply(p, q)

r = zeros(1,4);

r(1) = q(1)*p(1) - q(2)*p(2) - q(3)*p(3) - q(4)*p(4);
r(2) = q(1)*p(2) + q(2)*p(1) - q(3)*p(4) + q(4)*p(3);
r(3) = q(1)*p(3) + q(2)*p(4) + q(3)*p(1) - q(4)*p(2);
r(4) = q(1)*p(4) - q(2)*p(3) + q(3)*p(2) + q(4)*p(1);

%-----------------------------------------------------

p = [3 2 5 4];
q = [4 5 3 1];
r = quaternionmultiply(p,q);
r =

   -17    16    47     0
```

B.

```
function qinv = quaternioninverse(q)

qinv = [q(1) -q(2:4)] / (q*q');
%-----------------------------------------------

q = [8 2 3 1];
qinv = quaternioninverse(q)
qinv =

    0.1026   -0.0256   -0.0385   -0.0128

qinv * (q*q')
ans =

    8.0000   -2.0000   -3.0000   -1.0000

qinv * norm(q)
ans =

    0.9058   -0.2265   -0.3397   -0.1132
```

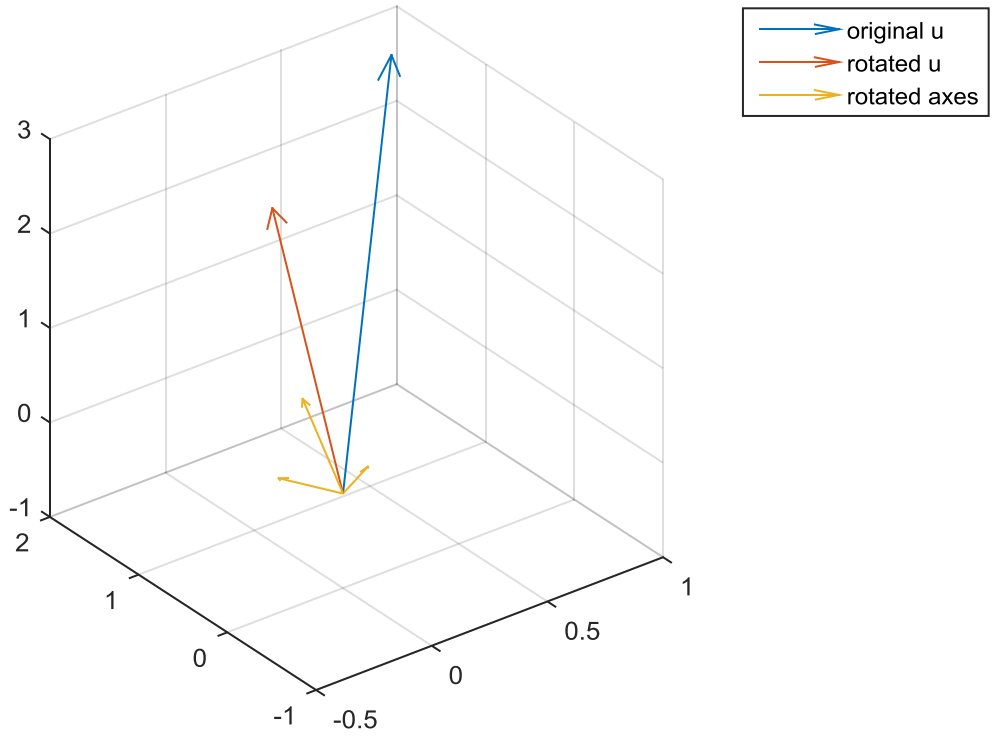
C.

```
function q = rotationquaternion(theta, v)

v = v/norm(v);
q = [cos(theta/2) sin(theta/2)*v];
%-----------------------------------------

x = [1 0 0];
theta = pi/6;
z = [0 0 1];
x = [0 x];

q = rotationquaternion(theta, z);
tmp = quaternionmultiply(quaternioninverse(q), x);
w = quaternionmultiply(tmp, q)

w =

         0    0.8660    -0.5000         0
```

D.

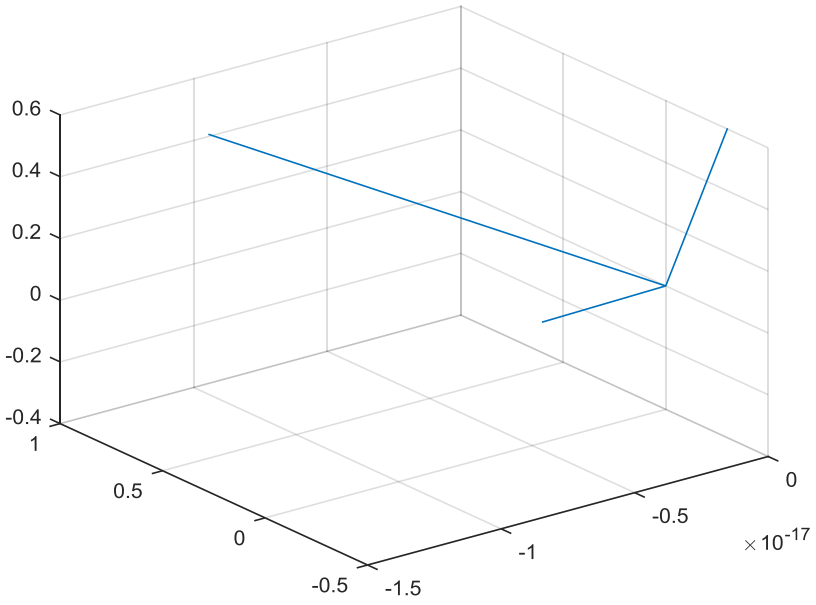
```
u = [1 2 3];
theta = pi/4;
v = [1 1 1];
u = [0 u];
q = rotationquaternion(theta, v);
tmp = quaternionmultiply(quaternioninverse(q), u);
w = quaternionmultiply(tmp, q)
q1 = quiver3(0,0,0, 1, 2, 3);
hold on;
q2 = quiver3(0,0,0, w(1), w(2), w(3));
```

```
hold on;
%rotate axes
tmp = quaternionmultiply(quaternioninverse(q), [0 1 0 0]);
x = quaternionmultiply(tmp, q);
tmp = quaternionmultiply(quaternioninverse(q), [0 0 1 0]);
y = quaternionmultiply(tmp, q);
tmp = quaternionmultiply(quaternioninverse(q), [0 0 0 1]);
z = quaternionmultiply(tmp, q);
q3 = quiver3([0,0,0], [0,0,0], [0,0,0], [x(1) y(1) z(1)], [x(2) y(2) z(2)],
[x(3), y(3), z(3)]);
legend([q1 q2 q3], 'original u', 'rotated u', 'rotated axes');
```

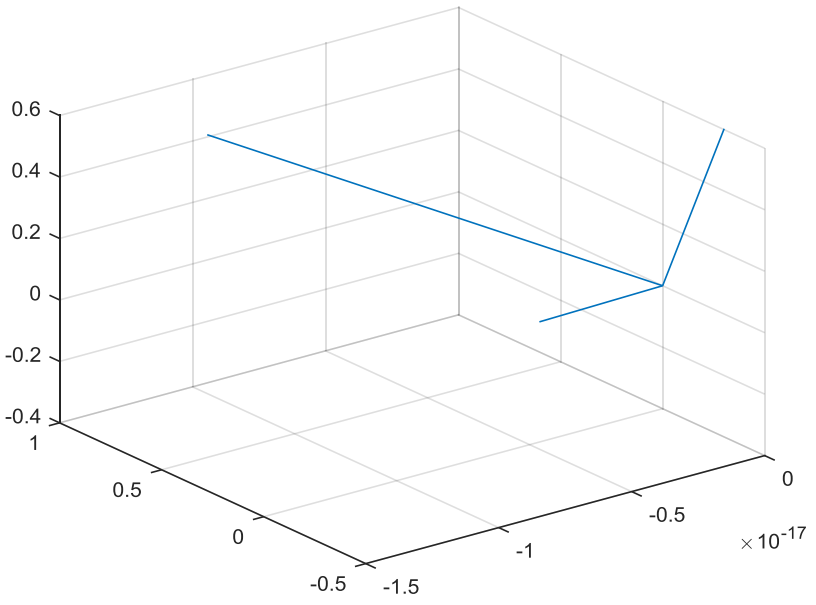


E.

```
theta = pi/3;
v = [1 1 1];
q = rotationquaternion(theta, v);
tmp = quaternionmultiply(quaternioninverse(q), [0 1 0 0]);
x = quaternionmultiply(tmp, q);
tmp = quaternionmultiply(quaternioninverse(q), [0 0 1 0]);
y = quaternionmultiply(tmp, q);
tmp = quaternionmultiply(quaternioninverse(q), [0 0 0 1]);
z = quaternionmultiply(tmp, q);
graph = quiver3([0,0,0], [0,0,0], [0,0,0], [x(1) y(1) z(1)], [x(2) y(2)
z(2)], [x(3), y(3), z(3)]);
graph.ShowArrowHead = 'off';
```




```
p = -q;
tmp = quaternionmultiply(quaternioninverse(p), [0 1 0 0]);
x = quaternionmultiply(tmp, p);
tmp = quaternionmultiply(quaternioninverse(p), [0 0 1 0]);
y = quaternionmultiply(tmp, p);
tmp = quaternionmultiply(quaternioninverse(p), [0 0 0 1]);
z = quaternionmultiply(tmp, p);
graph = quiver3([0,0,0], [0,0,0], [0,0,0], [x(1) y(1) z(1)], [x(2) y(2)
z(2)], [x(3), y(3), z(3)]);
graph.ShowArrowHead = 'off';
```



The two graphs look the same, using rotation q and p = -q.

Problem 3:

A.

```
A = zeros(14800, 13);
for i=1:13
    F = convertimage(sprintf('faces/basis/f%d.jpg', i));
    f = F(:);
    A(:,i) = f/norm(f);
end

%--------------------------------------
function A = convertimage(Img)

A = double(imread(Img))/255;
R = A(:,:,1);
G = A(:,:,2);
B = A(:,:,3);
A = (R+G+B)/3;
```

B.

```
T2 = convertimage('faces/tests/t2.jpg');
b = T2(:);
```

C.

```
x = pinv(A'*A)*A'*b;
v = A*x;
v = v/(max(v));
imshow(reshape(v,148,100));
```

```
imshow(T2);
```

```
%squared error
norm(v-b)^2
ans =

  295.5664
```

D.

```
x =

    3.3883
    6.2665
   -2.7240
   32.5422
   13.7122
   12.4288
   -6.4815
   -3.6926
   14.9529
  -16.5462
   12.0888
    0.5861
   23.4545
```

Based on the numbers above, the three basis images corresponding to absolute largest coefficients are: f4, f13, f10.

E.

```
RHO = corr(A)

  Columns 1 through 12

    1.0000    0.7795    0.7890    0.7363    0.6467    0.7252    0.7518
0.6863    0.7336    0.6895    0.7474    0.6838
    0.7795    1.0000    0.8511    0.7576    0.7304    0.7522    0.8225
0.7635    0.8120    0.7794    0.8189    0.7193
    0.7890    0.8511    1.0000    0.8183    0.7568    0.7670    0.8861
0.7723    0.8914    0.8243    0.8492    0.7969
    0.7363    0.7576    0.8183    1.0000    0.8242    0.8538    0.7551
0.6620    0.8038    0.7517    0.7610    0.7618
    0.6467    0.7304    0.7568    0.8242    1.0000    0.7922    0.7513
0.6919    0.8157    0.8221    0.7577    0.7650
    0.7252    0.7522    0.7670    0.8538    0.7922    1.0000    0.7258
0.6858    0.7477    0.7390    0.7161    0.7190
    0.7518    0.8225    0.8861    0.7551    0.7513    0.7258    1.0000
0.7801    0.9060    0.8846    0.8955    0.8116
    0.6863    0.7635    0.7723    0.6620    0.6919    0.6858    0.7801
1.0000    0.7774    0.7322    0.8152    0.8004
    0.7336    0.8120    0.8914    0.8038    0.8157    0.7477    0.9060
0.7774    1.0000    0.8889    0.9135    0.8539
    0.6895    0.7794    0.8243    0.7517    0.8221    0.7390    0.8846
0.7322    0.8889    1.0000    0.8354    0.7966
    0.7474    0.8189    0.8492    0.7610    0.7577    0.7161    0.8955
0.8152    0.9135    0.8354    1.0000    0.8171
    0.6838    0.7193    0.7969    0.7618    0.7650    0.7190    0.8116
0.8004    0.8539    0.7966    0.8171    1.0000
    0.7091    0.7694    0.8120    0.7698    0.7801    0.7246    0.8482
0.8308    0.8887    0.8168    0.8945    0.8915
```

```
  Column 13

    0.7091
    0.7694
    0.8120
    0.7698
    0.7801
    0.7246
    0.8482
    0.8308
    0.8887
    0.8168
    0.8945
    0.8915
    1.0000


RHO = corr(A);
RHO2 = RHO;
RHO2(logical(eye(13))) = 0;
[Y I] = max(RHO2)
```

Highest correlation: 0.9135, between images f9 and f11.

F.

```
COEFF = pca(RHO)

COEFF =

   -0.1624   -0.4603   -0.3172    0.3390   -0.3971   -0.1007    0.1143   -
0.0415   -0.2349   -0.1375    0.0713    0.1211
    0.0608   -0.2289   -0.3685   -0.2964    0.4712   -0.3551   -0.2131
0.5408    0.0310   -0.0088   -0.0076    0.0912
    0.1687   -0.0541   -0.3998    0.1601    0.2570    0.1229   -0.4365   -
0.4040   -0.3343   -0.1357    0.1276   -0.4170
   -0.1984    0.3628   -0.2328    0.4436    0.2679   -0.1811   -0.0451   -
0.2250    0.5976   -0.0847    0.0121    0.1113
   -0.0296    0.5594   -0.0013   -0.2822   -0.1098   -0.4657   -0.0314   -
0.2086   -0.4063    0.1995    0.1102   -0.0038
   -0.3115    0.2780   -0.1059    0.0980    0.4081    0.5306    0.3567
0.2281   -0.3711   -0.0227   -0.0006    0.0159
    0.3621   -0.0210   -0.3243   -0.0465   -0.0571    0.3071    0.0610   -
0.0744    0.1564    0.6759    0.3360    0.2341
    0.2917   -0.2622    0.4251   -0.1785    0.4179    0.1052    0.0145   -
0.4128    0.0227   -0.1619    0.0106    0.2035
    0.3501    0.1691   -0.2319    0.1126   -0.0155   -0.0429    0.0617   -
0.0787   -0.2459   -0.2608   -0.3330    0.6699
    0.2865    0.2702   -0.2471   -0.3710   -0.3257    0.3300   -0.0337
0.1216    0.2639   -0.4833    0.0059   -0.1770
    0.3839   -0.0460   -0.1402    0.1012    0.0985   -0.2098    0.5675   -
0.0492    0.0368    0.1494   -0.4571   -0.4543
    0.3124    0.1701    0.2923    0.4421   -0.0759    0.1179   -0.4706
0.3666   -0.1004    0.1873   -0.2841   -0.0662
    0.3720    0.0951    0.1804    0.3091    0.0642   -0.2085    0.2614
0.2504   -0.0758   -0.2702    0.6729   -0.0578
```

The first two principal components are the first 2 columns of the above matrix.

G.

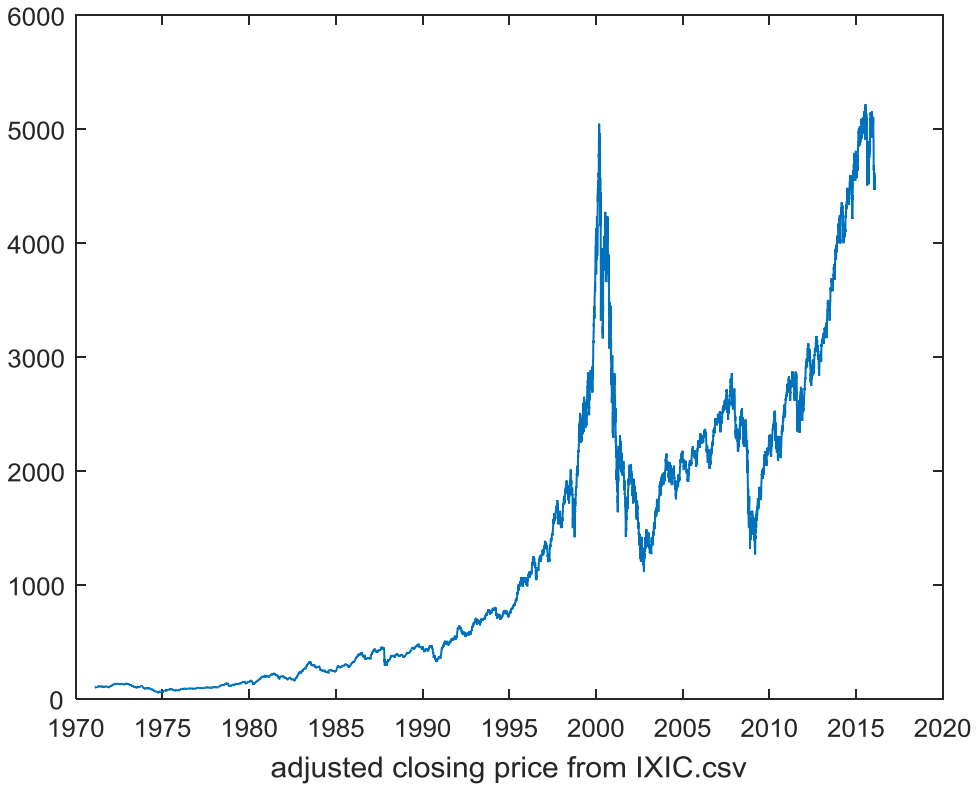
```
c1 = COEFF(:,1);
c2 = COEFF(:,2);
%pairwise distances
D = squareform(pdist([c1 c2]))
D(logical(eye(13))) = Inf;
m = min(D)
```

Images f7 and f11 have coordinates closest to each other.

Problem 4:

A.

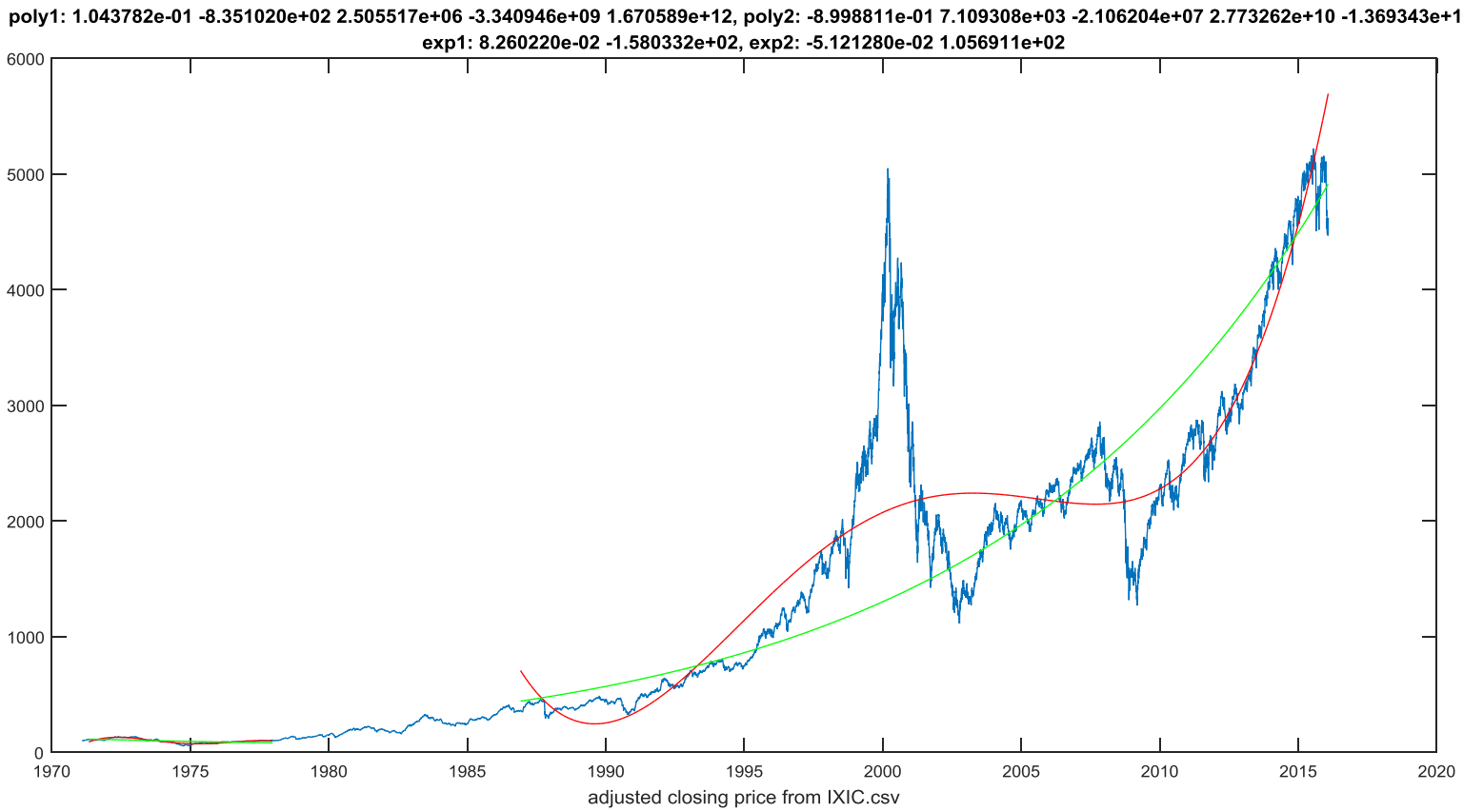
```
[time ixic] = read_stock('IXIC.csv');
```



B.

```
[time ixic] = read_stock('IXIC.csv');
t1 = time(2:7350);
y1 = ixic(2:7350);
t2 = time(9611:11287);
```

```
y2 = ixic(9611:11287);

%Polynomial Fit:
%First time period:
X4 = [t1.^4 t1.^3 t1.^2 t1 t1.^0];
c1p = X4 \ y1; %find coefficients of degree 4 polynomial

%Second time period:
X4 = [t2.^4 t2.^3 t2.^2 t2 t2.^0];
c1p = X4 \ y2; %find coefficients of degree 4 polynomial

%Exponential fit:
%First time period:
Ylog = log(y1);
T1 = [t1.^0 t1];
c1log = Ylog \ T1

%Second time period:
Ylog = log(y2);
T2 = [t2.^0 t2];
c2log = Ylog \ T2

%Polynomial Fit:
%First time period:
c1p = polyfit(t1, y1, 4); %find coefficients of degree 4 polynomial

%Second time period:
c2p = polyfit(t2, y2, 4); %find coefficients of degree 4 polynomial

%Exponential fit:
%First time period:
ylog = log(y1);
c1log = polyfit(t1, ylog, 1);
polylog1 = polyval(c1log, t1);

%Second time period:
ylog = log(y2);
c2log = polyfit(t2, ylog, 1);
polylog2 = polyval(c2log, t2);

hold on;
plot(t1, polyval(c1p, t1), 'r', t2, polyval(c2p, t2), 'r');
hold on;
plot(t1, exp(polylog1), 'g', t2, exp(polylog2), 'g');
hold on;
title(sprintf('poly1: %d %d %d %d %d, poly2: %d %d %d %d %d \nexp1: %d %d,
exp2: %d %d', c1p, c2p, c1log, c2log))
```

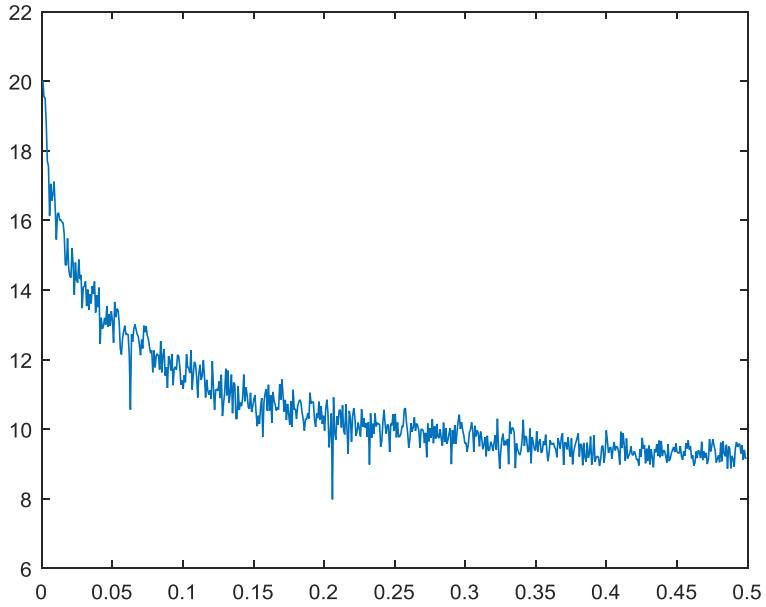


Squared Errors:

```
%squared errors:
polyerror1 = norm(polyval(c1p, t1) - y1)^2
polyerror2 = norm(polyval(c2p, t2) - y2)^2
experror1 = norm(exp(polylog1) - y1)^2
experror2 = norm(exp(polylog2) - y2)^2
polyerror1 =

   1.5922e+09


polyerror2 =

   9.2822e+04


experror1 =

   3.3657e+09


experror2 =

   4.4669e+05
```

It looks like the polynomial function fits better, since it has smaller errors for both time periods.

Problem 5:



The power spectrum value at the spike is 7.9806, based on the output of `log_power_spectrum(2:floor(n/2))`, which shows a suddenly low value in the middle of values around ~10.

```
I = find(v < 8)
I =
   259
```

The index is at 259, so looking at the frequency vector, the frequency corresponding to this spike is

```
frequencies(259)
ans =
    0.2051
```

Per month, this value is 0.2051 * 252/12 = 4.3071.