Contents


```
% HW 1 Problem 3 (b)
% Use Gaussian elimination to get determinant

clear
clc
close all

load('testproblem.mat')

% %% random problem generator
% nref=100;                %system size for larger reference problem
% A=randn(nref,nref);    %augmented matrix containing RHS of system of equations, in practice you'd want to check conditioning...
% b=randn(nref,1);    %RHS
```

Use the Gaussian elimination function to solve the same system (include scaled pivoting)

```
[Amod,ord,nuroich,detA]=Gel(A,b);

disp('Elimination with scaled pivoting on matrix:  ');
disp(Amod(ord,:));
xgauss=backsub(Amod(ord,:));
disp('Back substitution solution using Gaussian elimination result:  ');
disp(xgauss);
```

```
The total number of row interchanges is:
     6

The determinant of A is:
  -39.4247

Elimination with scaled pivoting on matrix:
  Columns 1 through 7

   -0.9300   -0.0209    0.1644    0.8810    0.1136   -0.2339    0.3362
         0   -1.1973    0.3897    0.0510   -0.6402   -0.7874    0.0867
   -0.0000         0    1.4314    1.1793   -2.4810   -0.7666   -0.1733
         0         0         0    1.8286   -2.4289    0.4258   -1.7899
         0   -0.0000         0    0.0000    1.4990    0.5853    0.7876
         0         0         0         0         0    2.7112   -2.6306
         0         0         0         0         0         0   -1.4250
         0         0         0         0         0         0         0

  Columns 8 through 9

   -0.3158    2.0375
    1.1351    0.7405
    1.6059    3.6406
    0.5231  -10.6202
   -0.0765   15.9078
   -2.7627  -24.2488
   -0.8058  -16.4214
    2.3358   18.6867

Back substitution solution using Gaussian elimination result:
    1.0000
    2.0000
    3.0000
    4.0000
    5.0000
```

```
    6.0000
    7.0000
    8.0000
```

Print step by step solution (Gauss elimination) for a simple system to illustrate

```
disp('%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%');
[Amodsmall,ord]=Gauss_elim(A,b,true);
disp('%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%');
```

```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
Starting Gauss elimination from row:
     1

Current state of matrix:
  Columns 1 through 7

   -1.0149   -2.1321    2.1778   -0.2730   -0.7841   -0.4677   -0.2841
   -0.4711    1.1454    1.1385    1.5763   -1.8054   -0.1249   -0.0867
    0.1370   -0.6291   -2.4969   -0.4809    1.8586    1.4790   -1.4694
   -0.2919   -1.2038    0.4413    0.3275   -0.6045   -0.8608    0.1922
    0.3018   -0.2539   -1.3981    0.6647    0.1034    0.7847   -0.8223
    0.3999   -1.4286   -0.2551    0.0852    0.5632    0.3086   -0.0942
   -0.9300   -0.0209    0.1644    0.8810    0.1136   -0.2339    0.3362
   -0.1768   -0.5607    0.7477    0.3232   -0.9047   -1.0570   -0.9047

  Columns 8 through 9

   -0.2883  -10.8600
    0.3501    3.9577
   -1.8359  -17.3415
    1.0360    1.3800
    2.4245   17.1229
    0.9594    8.8013
   -0.3158    2.0375
    0.4286  -11.5312

Interchanging rows:
     1

 and:
     7

Current matrix state after interchange:
  Columns 1 through 7

   -0.9300   -0.0209    0.1644    0.8810    0.1136   -0.2339    0.3362
   -0.4711    1.1454    1.1385    1.5763   -1.8054   -0.1249   -0.0867
    0.1370   -0.6291   -2.4969   -0.4809    1.8586    1.4790   -1.4694
   -0.2919   -1.2038    0.4413    0.3275   -0.6045   -0.8608    0.1922
    0.3018   -0.2539   -1.3981    0.6647    0.1034    0.7847   -0.8223
    0.3999   -1.4286   -0.2551    0.0852    0.5632    0.3086   -0.0942
   -1.0149   -2.1321    2.1778   -0.2730   -0.7841   -0.4677   -0.2841
   -0.1768   -0.5607    0.7477    0.3232   -0.9047   -1.0570   -0.9047

  Columns 8 through 9

   -0.3158    2.0375
    0.3501    3.9577
   -1.8359  -17.3415
    1.0360    1.3800
    2.4245   17.1229
    0.9594    8.8013
   -0.2883  -10.8600
    0.4286  -11.5312

Following elimination for row:
     1
```

```
 matrix state:
  Columns 1 through 7

   -0.9300   -0.0209    0.1644    0.8810    0.1136   -0.2339    0.3362
   -0.0000    1.1559    1.0552    1.1301   -1.8629   -0.0064   -0.2570
         0   -0.6322   -2.4727   -0.3511    1.8753    1.4445   -1.4199
         0   -1.1973    0.3897    0.0510   -0.6402   -0.7874    0.0867
         0   -0.2607   -1.3448    0.9506    0.1402    0.7088   -0.7132
         0   -1.4376   -0.1844    0.4640    0.6120    0.2081    0.0503
         0   -2.1093    1.9984   -1.2345   -0.9081   -0.2125   -0.6511
         0   -0.5567    0.7165    0.1557   -0.9263   -1.0125   -0.9686

  Columns 8 through 9

   -0.3158    2.0375
    0.5100    2.9256
   -1.8824  -17.0413
    1.1351    0.7405
    2.3220   17.7842
    0.8236    9.6775
    0.0564  -13.0837
    0.4887  -11.9186

Starting Gauss elimination from row:
     2

Current state of matrix:
  Columns 1 through 7

   -0.9300   -0.0209    0.1644    0.8810    0.1136   -0.2339    0.3362
   -0.0000    1.1559    1.0552    1.1301   -1.8629   -0.0064   -0.2570
         0   -0.6322   -2.4727   -0.3511    1.8753    1.4445   -1.4199
         0   -1.1973    0.3897    0.0510   -0.6402   -0.7874    0.0867
         0   -0.2607   -1.3448    0.9506    0.1402    0.7088   -0.7132
         0   -1.4376   -0.1844    0.4640    0.6120    0.2081    0.0503
         0   -2.1093    1.9984   -1.2345   -0.9081   -0.2125   -0.6511
         0   -0.5567    0.7165    0.1557   -0.9263   -1.0125   -0.9686

  Columns 8 through 9

   -0.3158    2.0375
    0.5100    2.9256
   -1.8824  -17.0413
    1.1351    0.7405
    2.3220   17.7842
    0.8236    9.6775
    0.0564  -13.0837
    0.4887  -11.9186

Interchanging rows:
     2

 and:
     4

Current matrix state after interchange:
  Columns 1 through 7

   -0.9300   -0.0209    0.1644    0.8810    0.1136   -0.2339    0.3362
         0   -1.1973    0.3897    0.0510   -0.6402   -0.7874    0.0867
         0   -0.6322   -2.4727   -0.3511    1.8753    1.4445   -1.4199
   -0.0000    1.1559    1.0552    1.1301   -1.8629   -0.0064   -0.2570
         0   -0.2607   -1.3448    0.9506    0.1402    0.7088   -0.7132
         0   -1.4376   -0.1844    0.4640    0.6120    0.2081    0.0503
         0   -2.1093    1.9984   -1.2345   -0.9081   -0.2125   -0.6511
         0   -0.5567    0.7165    0.1557   -0.9263   -1.0125   -0.9686

  Columns 8 through 9

   -0.3158    2.0375
    1.1351    0.7405
   -1.8824  -17.0413
    0.5100    2.9256
```

```
    2.3220   17.7842
    0.8236    9.6775
    0.0564  -13.0837
    0.4887  -11.9186

Following elimination for row:
     2

 matrix state:
  Columns 1 through 7

   -0.9300   -0.0209    0.1644    0.8810    0.1136   -0.2339    0.3362
         0   -1.1973    0.3897    0.0510   -0.6402   -0.7874    0.0867
         0         0   -2.6784   -0.3781    2.2133    1.8603   -1.4656
   -0.0000         0    1.4314    1.1793   -2.4810   -0.7666   -0.1733
         0         0   -1.4296    0.9395    0.2796    0.8802   -0.7320
         0   -0.0000   -0.6523    0.4028    1.3807    1.1535   -0.0537
         0         0    1.3118   -1.3244    0.2197    1.1747   -0.8038
         0         0    0.5353    0.1320   -0.6287   -0.6464   -1.0089

  Columns 8 through 9

   -0.3158    2.0375
    1.1351    0.7405
   -2.4817  -17.4323
    1.6059    3.6406
    2.0748   17.6229
   -0.5393    8.7884
   -1.9433  -14.3884
   -0.0391  -12.2629

Starting Gauss elimination from row:
     3

Current state of matrix:
  Columns 1 through 7

   -0.9300   -0.0209    0.1644    0.8810    0.1136   -0.2339    0.3362
         0   -1.1973    0.3897    0.0510   -0.6402   -0.7874    0.0867
         0         0   -2.6784   -0.3781    2.2133    1.8603   -1.4656
   -0.0000         0    1.4314    1.1793   -2.4810   -0.7666   -0.1733
         0         0   -1.4296    0.9395    0.2796    0.8802   -0.7320
         0   -0.0000   -0.6523    0.4028    1.3807    1.1535   -0.0537
         0         0    1.3118   -1.3244    0.2197    1.1747   -0.8038
         0         0    0.5353    0.1320   -0.6287   -0.6464   -1.0089

  Columns 8 through 9

   -0.3158    2.0375
    1.1351    0.7405
   -2.4817  -17.4323
    1.6059    3.6406
    2.0748   17.6229
   -0.5393    8.7884
   -1.9433  -14.3884
   -0.0391  -12.2629

Interchanging rows:
     3

 and:
     2

Current matrix state after interchange:
  Columns 1 through 7

   -0.9300   -0.0209    0.1644    0.8810    0.1136   -0.2339    0.3362
         0   -1.1973    0.3897    0.0510   -0.6402   -0.7874    0.0867
   -0.0000         0    1.4314    1.1793   -2.4810   -0.7666   -0.1733
         0         0   -2.6784   -0.3781    2.2133    1.8603   -1.4656
         0         0   -1.4296    0.9395    0.2796    0.8802   -0.7320
         0   -0.0000   -0.6523    0.4028    1.3807    1.1535   -0.0537
         0         0    1.3118   -1.3244    0.2197    1.1747   -0.8038
```

```
         0         0    0.5353    0.1320   -0.6287   -0.6464   -1.0089

  Columns 8 through 9

   -0.3158    2.0375
    1.1351    0.7405
    1.6059    3.6406
   -2.4817  -17.4323
    2.0748   17.6229
   -0.5393    8.7884
   -1.9433  -14.3884
   -0.0391  -12.2629

Following elimination for row:
     3

 matrix state:
  Columns 1 through 7

   -0.9300   -0.0209    0.1644    0.8810    0.1136   -0.2339    0.3362
         0   -1.1973    0.3897    0.0510   -0.6402   -0.7874    0.0867
   -0.0000         0    1.4314    1.1793   -2.4810   -0.7666   -0.1733
         0         0         0    1.8286   -2.4289    0.4258   -1.7899
         0         0         0    2.1174   -2.1982    0.1146   -0.9052
         0   -0.0000         0    0.9402    0.2501    0.8042   -0.1327
         0         0         0   -2.4051    2.4932    1.8773   -0.6449
         0         0         0   -0.3090    0.2990   -0.3597   -0.9441

  Columns 8 through 9

   -0.3158    2.0375
    1.1351    0.7405
    1.6059    3.6406
    0.5231  -10.6202
    3.6787   21.2589
    0.1925   10.4474
   -3.4149  -17.7245
   -0.6396  -13.6243

Starting Gauss elimination from row:
     4

Current state of matrix:
  Columns 1 through 7

   -0.9300   -0.0209    0.1644    0.8810    0.1136   -0.2339    0.3362
         0   -1.1973    0.3897    0.0510   -0.6402   -0.7874    0.0867
   -0.0000         0    1.4314    1.1793   -2.4810   -0.7666   -0.1733
         0         0         0    1.8286   -2.4289    0.4258   -1.7899
         0         0         0    2.1174   -2.1982    0.1146   -0.9052
         0   -0.0000         0    0.9402    0.2501    0.8042   -0.1327
         0         0         0   -2.4051    2.4932    1.8773   -0.6449
         0         0         0   -0.3090    0.2990   -0.3597   -0.9441

  Columns 8 through 9

   -0.3158    2.0375
    1.1351    0.7405
    1.6059    3.6406
    0.5231  -10.6202
    3.6787   21.2589
    0.1925   10.4474
   -3.4149  -17.7245
   -0.6396  -13.6243

Following elimination for row:
     4

 matrix state:
  Columns 1 through 7

   -0.9300   -0.0209    0.1644    0.8810    0.1136   -0.2339    0.3362
         0   -1.1973    0.3897    0.0510   -0.6402   -0.7874    0.0867
```

```
   -0.0000         0    1.4314    1.1793   -2.4810   -0.7666   -0.1733
         0         0         0    1.8286   -2.4289    0.4258   -1.7899
         0         0         0         0    0.6143   -0.3784    1.1674
         0   -0.0000         0    0.0000    1.4990    0.5853    0.7876
         0         0         0         0   -0.7015    2.4373   -2.9992
         0         0         0         0   -0.1114   -0.2878   -1.2465

  Columns 8 through 9

   -0.3158    2.0375
    1.1351    0.7405
    1.6059    3.6406
    0.5231  -10.6202
    3.0729   33.5563
   -0.0765   15.9078
   -2.7269  -31.6931
   -0.5512  -15.4189

Starting Gauss elimination from row:
     5

Current state of matrix:
  Columns 1 through 7

   -0.9300   -0.0209    0.1644    0.8810    0.1136   -0.2339    0.3362
         0   -1.1973    0.3897    0.0510   -0.6402   -0.7874    0.0867
   -0.0000         0    1.4314    1.1793   -2.4810   -0.7666   -0.1733
         0         0         0    1.8286   -2.4289    0.4258   -1.7899
         0         0         0         0    0.6143   -0.3784    1.1674
         0   -0.0000         0    0.0000    1.4990    0.5853    0.7876
         0         0         0         0   -0.7015    2.4373   -2.9992
         0         0         0         0   -0.1114   -0.2878   -1.2465

  Columns 8 through 9

   -0.3158    2.0375
    1.1351    0.7405
    1.6059    3.6406
    0.5231  -10.6202
    3.0729   33.5563
   -0.0765   15.9078
   -2.7269  -31.6931
   -0.5512  -15.4189

Interchanging rows:
     5

 and:
     6

Current matrix state after interchange:
  Columns 1 through 7

   -0.9300   -0.0209    0.1644    0.8810    0.1136   -0.2339    0.3362
         0   -1.1973    0.3897    0.0510   -0.6402   -0.7874    0.0867
   -0.0000         0    1.4314    1.1793   -2.4810   -0.7666   -0.1733
         0         0         0    1.8286   -2.4289    0.4258   -1.7899
         0   -0.0000         0    0.0000    1.4990    0.5853    0.7876
         0         0         0         0    0.6143   -0.3784    1.1674
         0         0         0         0   -0.7015    2.4373   -2.9992
         0         0         0         0   -0.1114   -0.2878   -1.2465

  Columns 8 through 9

   -0.3158    2.0375
    1.1351    0.7405
    1.6059    3.6406
    0.5231  -10.6202
   -0.0765   15.9078
    3.0729   33.5563
   -2.7269  -31.6931
   -0.5512  -15.4189
```

```
Following elimination for row:
     5

 matrix state:
  Columns 1 through 7

   -0.9300   -0.0209    0.1644    0.8810    0.1136   -0.2339    0.3362
         0   -1.1973    0.3897    0.0510   -0.6402   -0.7874    0.0867
   -0.0000         0    1.4314    1.1793   -2.4810   -0.7666   -0.1733
         0         0         0    1.8286   -2.4289    0.4258   -1.7899
         0   -0.0000         0    0.0000    1.4990    0.5853    0.7876
         0         0         0         0         0   -0.6183    0.8447
         0         0         0         0         0    2.7112   -2.6306
         0         0         0         0         0   -0.2443   -1.1880

  Columns 8 through 9

   -0.3158    2.0375
    1.1351    0.7405
    1.6059    3.6406
    0.5231  -10.6202
   -0.0765   15.9078
    3.1043   27.0374
   -2.7627  -24.2488
   -0.5569  -14.2366

Starting Gauss elimination from row:
     6

Current state of matrix:
  Columns 1 through 7

   -0.9300   -0.0209    0.1644    0.8810    0.1136   -0.2339    0.3362
         0   -1.1973    0.3897    0.0510   -0.6402   -0.7874    0.0867
   -0.0000         0    1.4314    1.1793   -2.4810   -0.7666   -0.1733
         0         0         0    1.8286   -2.4289    0.4258   -1.7899
         0   -0.0000         0    0.0000    1.4990    0.5853    0.7876
         0         0         0         0         0   -0.6183    0.8447
         0         0         0         0         0    2.7112   -2.6306
         0         0         0         0         0   -0.2443   -1.1880

  Columns 8 through 9

   -0.3158    2.0375
    1.1351    0.7405
    1.6059    3.6406
    0.5231  -10.6202
   -0.0765   15.9078
    3.1043   27.0374
   -2.7627  -24.2488
   -0.5569  -14.2366

Interchanging rows:
     5

 and:
     1

Current matrix state after interchange:
  Columns 1 through 7

   -0.9300   -0.0209    0.1644    0.8810    0.1136   -0.2339    0.3362
         0   -1.1973    0.3897    0.0510   -0.6402   -0.7874    0.0867
   -0.0000         0    1.4314    1.1793   -2.4810   -0.7666   -0.1733
         0         0         0    1.8286   -2.4289    0.4258   -1.7899
         0   -0.0000         0    0.0000    1.4990    0.5853    0.7876
         0         0         0         0         0    2.7112   -2.6306
         0         0         0         0         0   -0.6183    0.8447
         0         0         0         0         0   -0.2443   -1.1880

  Columns 8 through 9

   -0.3158    2.0375
```

```
    1.1351    0.7405
    1.6059    3.6406
    0.5231  -10.6202
   -0.0765   15.9078
   -2.7627  -24.2488
    3.1043   27.0374
   -0.5569  -14.2366

Following elimination for row:
     6

 matrix state:
  Columns 1 through 7

   -0.9300   -0.0209    0.1644    0.8810    0.1136   -0.2339    0.3362
         0   -1.1973    0.3897    0.0510   -0.6402   -0.7874    0.0867
   -0.0000         0    1.4314    1.1793   -2.4810   -0.7666   -0.1733
         0         0         0    1.8286   -2.4289    0.4258   -1.7899
         0   -0.0000         0    0.0000    1.4990    0.5853    0.7876
         0         0         0         0         0    2.7112   -2.6306
         0         0         0         0         0         0    0.2448
         0         0         0         0         0         0   -1.4250

  Columns 8 through 9

   -0.3158    2.0375
    1.1351    0.7405
    1.6059    3.6406
    0.5231  -10.6202
   -0.0765   15.9078
   -2.7627  -24.2488
    2.4743   21.5075
   -0.8058  -16.4214

Starting Gauss elimination from row:
     7

Current state of matrix:
  Columns 1 through 7

   -0.9300   -0.0209    0.1644    0.8810    0.1136   -0.2339    0.3362
         0   -1.1973    0.3897    0.0510   -0.6402   -0.7874    0.0867
   -0.0000         0    1.4314    1.1793   -2.4810   -0.7666   -0.1733
         0         0         0    1.8286   -2.4289    0.4258   -1.7899
         0   -0.0000         0    0.0000    1.4990    0.5853    0.7876
         0         0         0         0         0    2.7112   -2.6306
         0         0         0         0         0         0    0.2448
         0         0         0         0         0         0   -1.4250

  Columns 8 through 9

   -0.3158    2.0375
    1.1351    0.7405
    1.6059    3.6406
    0.5231  -10.6202
   -0.0765   15.9078
   -2.7627  -24.2488
    2.4743   21.5075
   -0.8058  -16.4214

Interchanging rows:
     5

 and:
     8

Current matrix state after interchange:
  Columns 1 through 7

   -0.9300   -0.0209    0.1644    0.8810    0.1136   -0.2339    0.3362
         0   -1.1973    0.3897    0.0510   -0.6402   -0.7874    0.0867
   -0.0000         0    1.4314    1.1793   -2.4810   -0.7666   -0.1733
         0         0         0    1.8286   -2.4289    0.4258   -1.7899
```

```
         0   -0.0000         0    0.0000    1.4990    0.5853    0.7876
         0         0         0         0         0    2.7112   -2.6306
         0         0         0         0         0         0   -1.4250
         0         0         0         0         0         0    0.2448

  Columns 8 through 9

   -0.3158    2.0375
    1.1351    0.7405
    1.6059    3.6406
    0.5231  -10.6202
   -0.0765   15.9078
   -2.7627  -24.2488
   -0.8058  -16.4214
    2.4743   21.5075

Following elimination for row:
     7

 matrix state:
  Columns 1 through 7

   -0.9300   -0.0209    0.1644    0.8810    0.1136   -0.2339    0.3362
         0   -1.1973    0.3897    0.0510   -0.6402   -0.7874    0.0867
   -0.0000         0    1.4314    1.1793   -2.4810   -0.7666   -0.1733
         0         0         0    1.8286   -2.4289    0.4258   -1.7899
         0   -0.0000         0    0.0000    1.4990    0.5853    0.7876
         0         0         0         0         0    2.7112   -2.6306
         0         0         0         0         0         0   -1.4250
         0         0         0         0         0         0         0

  Columns 8 through 9

   -0.3158    2.0375
    1.1351    0.7405
    1.6059    3.6406
    0.5231  -10.6202
   -0.0765   15.9078
   -2.7627  -24.2488
   -0.8058  -16.4214
    2.3358   18.6867

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
```

Compare against built in MATLAB solution

```
xmat=A\b;
disp('Built-in MATLAB solution');
disp(xmat);
Errrsol = xmat - xgauss;
disp('The difference is (sol for x): ')
disp(Errrsol)
```

```
Built-in MATLAB solution
    1.0000
    2.0000
    3.0000
    4.0000
    5.0000
    6.0000
    7.0000
    8.0000

The difference is (sol for x):
   1.0e-14 *

    0.2998
   -0.0444
    0.1332
    0.0444
```

```
   -0.1776
   -0.1776
    0.1776
   -0.1776
```

MATLAB built-in sol. 4 det.

```
dmat = det(A);
disp('Built-in MATLAB solution for determinant');
disp(dmat);
Errrdet = dmat - detA;
disp('The difference is (determinant): ')
disp(Errrdet)
```

```
Built-in MATLAB solution for determinant
  -39.4247

The difference is (determinant):
     0
```

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