THE UNIVERSITY OF TEXAS
AT AUSTIN

CS363D STATISTICAL LEARNING AND DATA MINING

Homework 02

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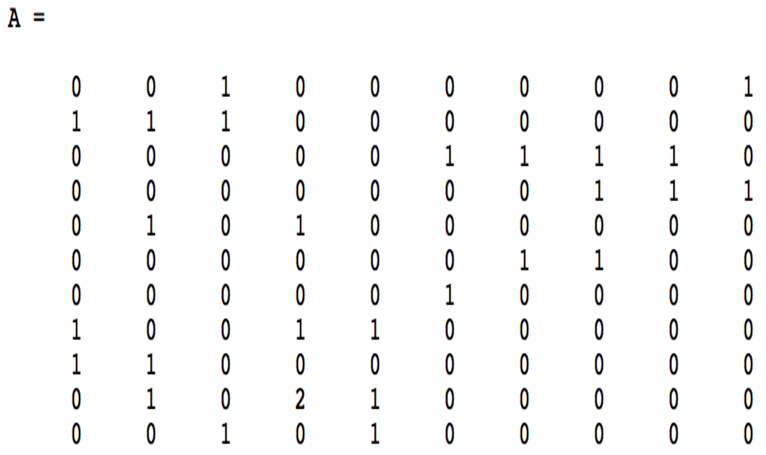
Contents

List of Figures

1 Data Transformation and Normalization

1.1 Transformation



```
A =

     0     0     1     0     0     0     0     0     0     1
     1     1     1     0     0     0     0     0     0     0
     0     0     0     0     0     1     1     1     1     0
     0     0     0     0     0     0     0     1     1     1
     0     1     0     1     0     0     0     0     0     0
     0     0     0     0     0     0     1     1     0     0
     0     0     0     0     0     1     0     0     0     0
     1     0     0     1     1     0     0     0     0     0
     1     1     0     0     0     0     0     0     0     0
     0     1     0     2     1     0     0     0     0     0
     0     0     1     0     1     0     0     0     0     0
```

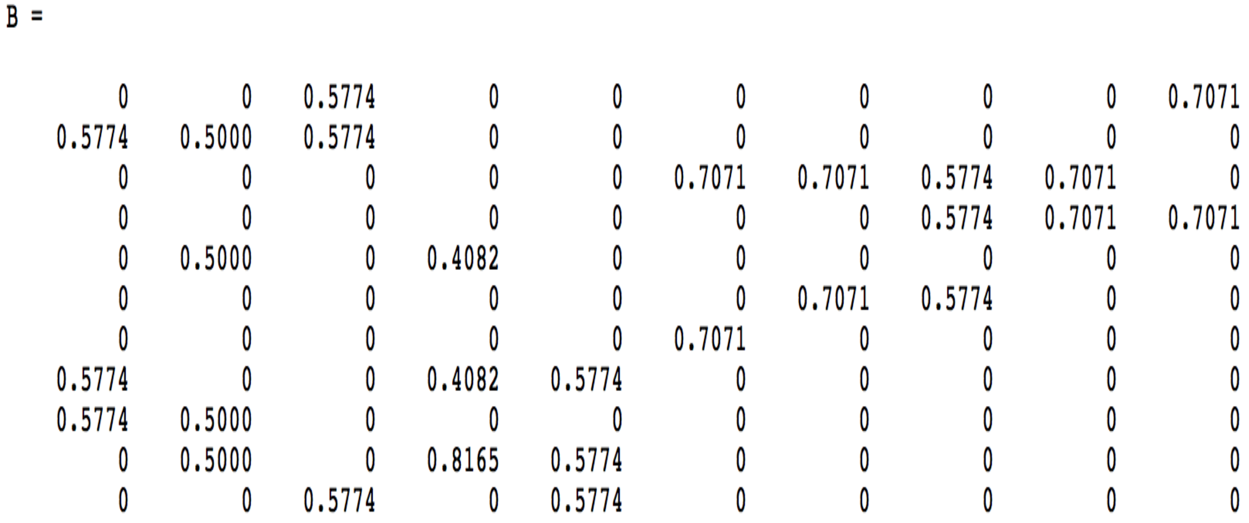
where each document vector (column) correponds to the frequency of terms

$(business, computer, economy, growth, operating, recession, recovery, released, software, system, virus)$

and each term vector (row) represents term frequency in documents

$$(c1, c2, c3, c4, c5, m6, m7, m8, m9, m10)$$

1.2 Normalization

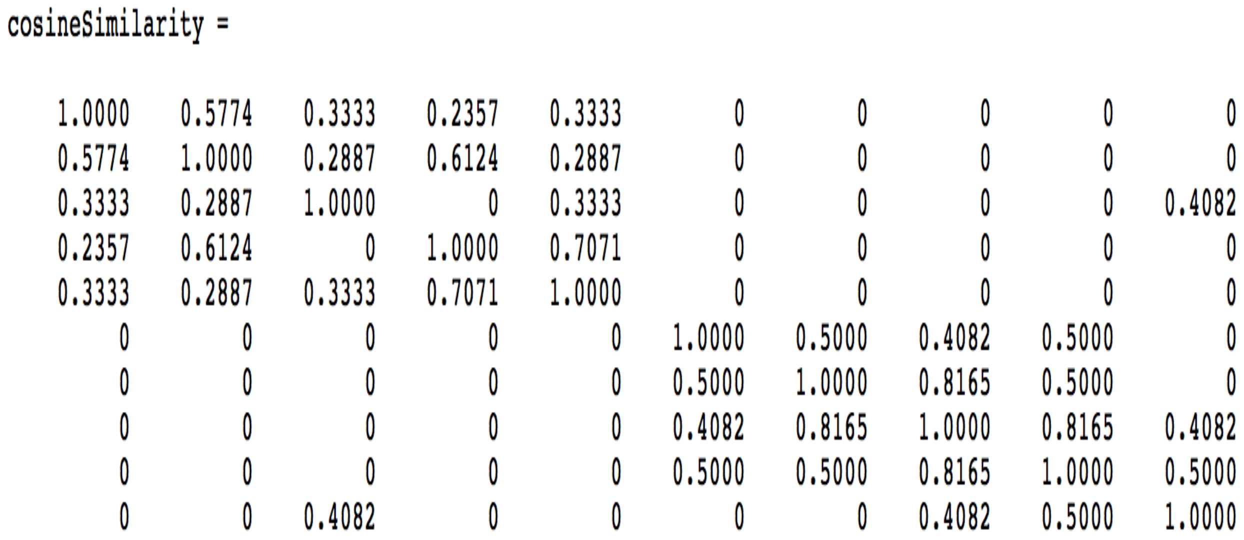


```
B =

         0         0    0.5774         0         0         0         0         0         0    0.7071
    0.5774    0.5000    0.5774         0         0         0         0         0         0         0
         0         0         0         0         0    0.7071    0.7071    0.5774    0.7071         0
         0         0         0         0         0         0         0    0.5774    0.7071    0.7071
         0    0.5000         0    0.4082         0         0         0         0         0         0
         0         0         0         0         0         0    0.7071    0.5774         0         0
         0         0         0         0         0    0.7071         0         0         0         0
    0.5774         0         0    0.4082    0.5774         0         0         0         0         0
    0.5774    0.5000         0         0         0         0         0         0         0         0
         0    0.5000         0    0.8165    0.5774         0         0         0         0         0
         0         0    0.5774         0    0.5774         0         0         0         0         0
```

2 Cosine Similarity

We compute the $B^T B$ and get the following result,

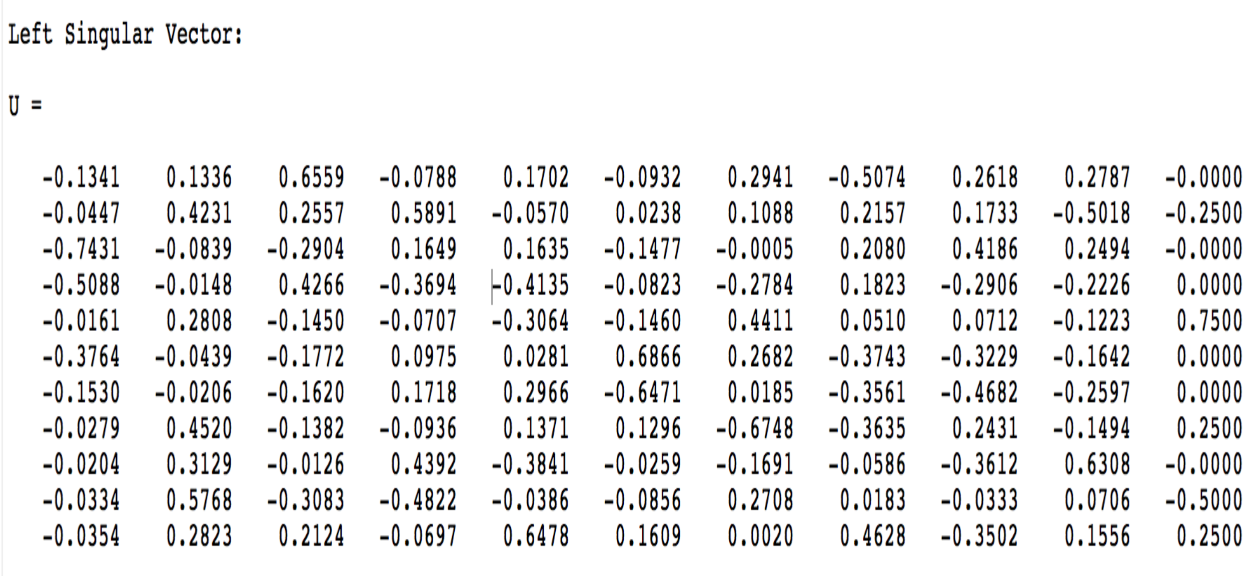


```
cosineSimilarity =

    1.0000    0.5774    0.3333    0.2357    0.3333         0         0         0         0         0
    0.5774    1.0000    0.2887    0.6124    0.2887         0         0         0         0         0
    0.3333    0.2887    1.0000         0    0.3333         0         0         0         0    0.4082
    0.2357    0.6124         0    1.0000    0.7071         0         0         0         0         0
    0.3333    0.2887    0.3333    0.7071    1.0000         0         0         0         0         0
         0         0         0         0         0    1.0000    0.5000    0.4082    0.5000         0
         0         0         0         0         0    0.5000    1.0000    0.8165    0.5000         0
         0         0         0         0         0    0.4082    0.8165    1.0000    0.8165    0.4082
         0         0         0         0         0    0.5000    0.5000    0.8165    1.0000    0.5000
         0         0    0.4082         0         0         0         0    0.4082    0.5000    1.0000
```

Note that each entry e_{ij} represents the cosine similarity between document i and document j.

3 Singular Value Decomposition

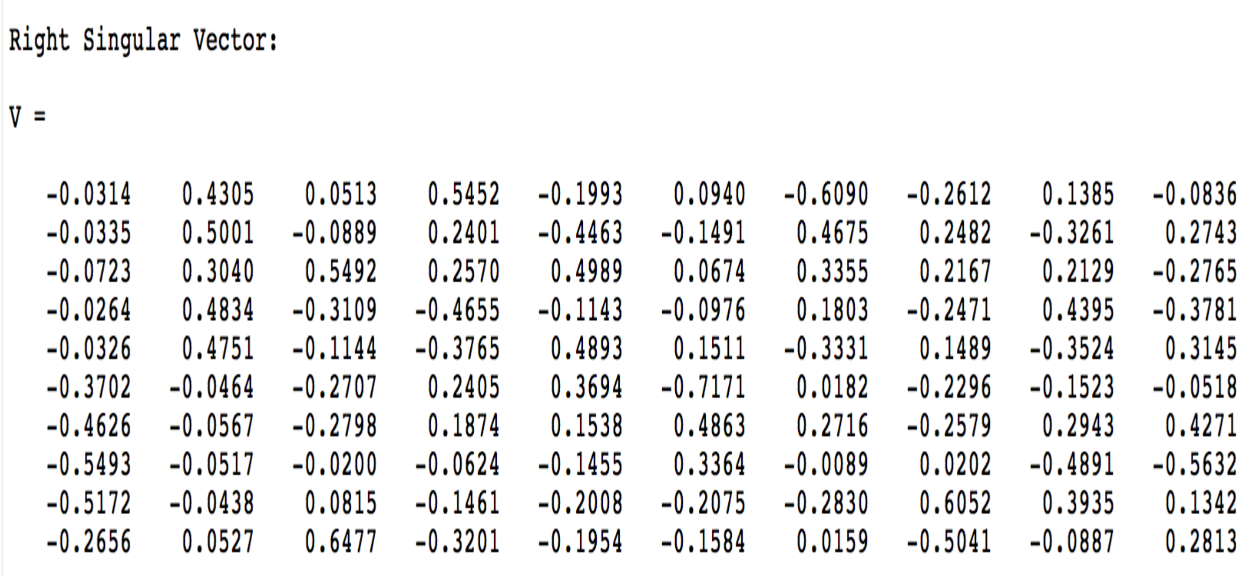


```
Left Singular Vector:

U =

  -0.1341    0.1336    0.6559   -0.0788    0.1702   -0.0932    0.2941   -0.5074    0.2618    0.2787   -0.0000
  -0.0447    0.4231    0.2557    0.5891   -0.0570    0.0238    0.1088    0.2157    0.1733   -0.5018   -0.2500
  -0.7431   -0.0839   -0.2904    0.1649    0.1635   -0.1477   -0.0005    0.2080    0.4186    0.2494   -0.0000
  -0.5088   -0.0148    0.4266   -0.3694   -0.4135   -0.0823   -0.2784    0.1823   -0.2906   -0.2226    0.0000
  -0.0161    0.2808   -0.1450   -0.0707   -0.3064   -0.1460    0.4411    0.0510    0.0712   -0.1223    0.7500
  -0.3764   -0.0439   -0.1772    0.0975    0.0281    0.6866    0.2682   -0.3743   -0.3229   -0.1642    0.0000
  -0.1530   -0.0206   -0.1620    0.1718    0.2966   -0.6471    0.0185   -0.3561   -0.4682   -0.2597    0.0000
  -0.0279    0.4520   -0.1382   -0.0936    0.1371    0.1296   -0.6748   -0.3635    0.2431   -0.1494    0.2500
  -0.0204    0.3129   -0.0126    0.4392   -0.3841   -0.0259   -0.1691   -0.0586   -0.3612    0.6308   -0.0000
  -0.0334    0.5768   -0.3083   -0.4822   -0.0386   -0.0856    0.2708    0.0183   -0.0333    0.0706   -0.5000
  -0.0354    0.2823    0.2124   -0.0697    0.6478    0.1609    0.0020    0.4628   -0.3502    0.1556    0.2500
```

Figure 1: Each Column is a Left Singular Vector



```
Right Singular Vector:

V =

  -0.0314    0.4305    0.0513    0.5452   -0.1993    0.0940   -0.6090   -0.2612    0.1385   -0.0836
  -0.0335    0.5001   -0.0889    0.2401   -0.4463   -0.1491    0.4675    0.2482   -0.3261    0.2743
  -0.0723    0.3040    0.5492    0.2570    0.4989    0.0674    0.3355    0.2167    0.2129   -0.2765
  -0.0264    0.4834   -0.3109   -0.4655   -0.1143   -0.0976    0.1803   -0.2471    0.4395   -0.3781
  -0.0326    0.4751   -0.1144   -0.3765    0.4893    0.1511   -0.3331    0.1489   -0.3524    0.3145
  -0.3702   -0.0464   -0.2707    0.2405    0.3694   -0.7171    0.0182   -0.2296   -0.1523   -0.0518
  -0.4626   -0.0567   -0.2798    0.1874    0.1538    0.4863    0.2716   -0.2579    0.2943    0.4271
  -0.5493   -0.0517   -0.0200   -0.0624   -0.1455    0.3364   -0.0089    0.0202   -0.4891   -0.5632
  -0.5172   -0.0438    0.0815   -0.1461   -0.2008   -0.2075   -0.2830    0.6052    0.3935    0.1342
  -0.2656    0.0527    0.6477   -0.3201   -0.1954   -0.1584    0.0159   -0.5041   -0.0887    0.2813
```

Figure 2: Each Column is a Right Singular Vector

Singluar Values are respectively,

1.7114 , 1.5933 , 1.1817 , 0.9899 , 0.8807 , 0.7837 , 0.6969 ,0.4560 , 0.2300 , 0.1409

4 Plot first two left/right singular matrix

Two Left singular Vectors:
U1 = (-0.1341 , -0.0447 , -0.7431, -0.5088 , -0.0161 , -0.3764 , -0.1530 , -0.0279 , -0.0204 -0.0334 -0.0354)
U2 = (0.1336 , 0.4231 , -0.0839 , -0.0148 , 0.2808 , -0.0439 , -0.0206 , 0.4520 , 0.3129 , 0.5768 , 0.2823)

Two Right singular Vectors:
V1 = (-0.0314 , -0.0335 , -0.0723 , -0.0264 , -0.0326 , -0.3702 , -0.4626, -0.5493 , -0.5172 , -0.2656)
V2 = (0.4305 , 0.5001 , 0.3040 , 0.4834 , 0.4751 , -0.0464 , -0.0567, -0.0517 , -0.0438 , 0.0527)

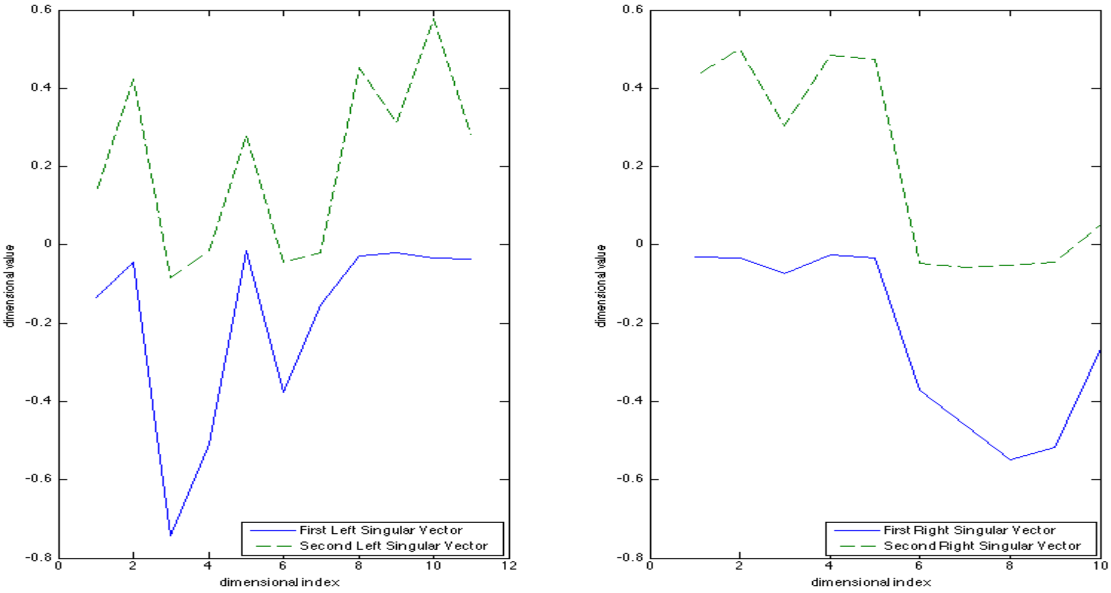


Figure 3: Two Left Columns and Right Columns

5 Plot the projected document vectors

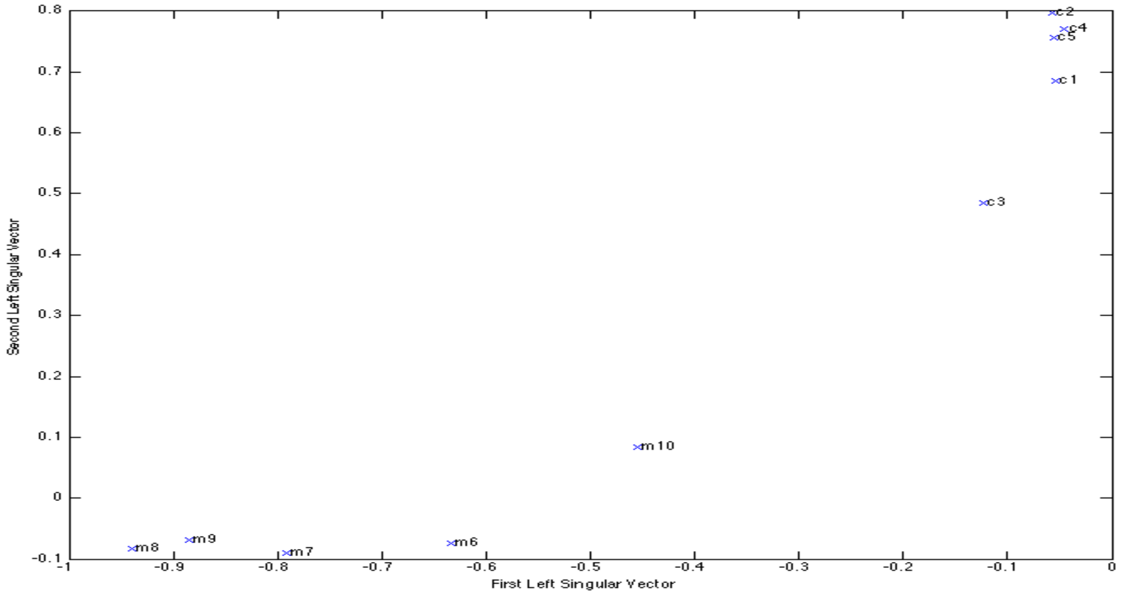


Figure 4: Projected Document Vectors

6 Plot the projected term vectors

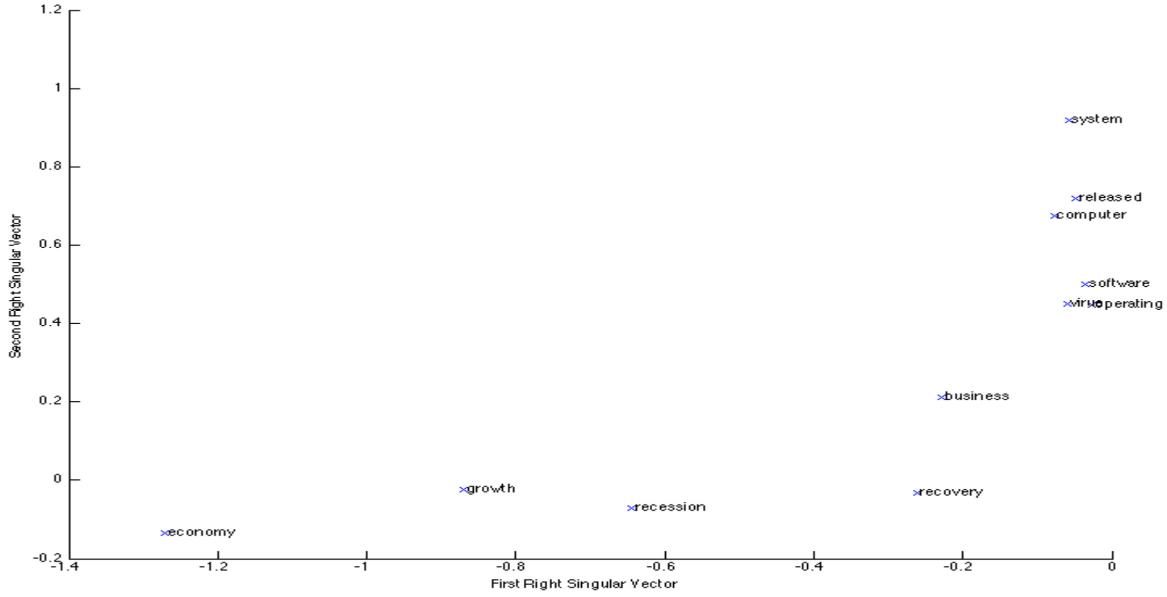


Figure 5: Projected Term Vectors

7 Source Code

```
function y = homework2 ()

%% data input
c1 = {'released' 'software' 'computer'};
c2 = {'operating' 'system' 'computer' 'software'};
c3 = {'computer','virus', 'business'};
c4 = {'system','released', 'operating', 'system'};
c5 = {'released', 'virus', 'system'};
m6 = {'recovery', 'economy'};
m7 = {'economy', 'recession'};
m8 = {'growth', 'economy', 'recession'};
m9 = {'economy', 'growth'};
m10 = {'growth', 'business'};

documents = {c1, c2, c3, c4, c5, m6, m7, m8, m9, m10};

%% keyword generation
collections = [c1, c2, c3, c4, c5, m6, m7, m8, m9, m10];
keywords = unique(collections);
keywords

%% 1(a). generate A matrix
A = [];
for i = 1:size(documents,2),
    term_vector = zeros(size(keywords));
    document = documents{i};
    for j = 1:size(document,2),
        word = document{j};
        indx = find(strcmp(word, keywords));
        term_vector(indx) = term_vector(indx) + 1;
    end
    A = [A term_vector'];
end
A

%% 1(b). Normalize matrix A to get matrix B,
%  where each column (document) vector of B has unit l -norm.
%for col = 1:size(A,2),
%    ltnorm = norm(A(:,col));
%    B(:,col) = A(:,col) / ltnorm;
%end
B = normc(A)


%% 2. Cosine Similarity
cosineSimilarity = B'* B

%% 3. Singular Value Decomposition
[U,Sigma,V] = svd(B);
disp('Left Singular Vector:')
U

disp('Right Singular Vector:')
V

disp('Singluar Values: ')
singularValues = [];
for i = 1:min(size(Sigma)),
    singularValues = [singularValues Sigma(i,i)];
end
disp(singularValues)

%% 4. Plot the first two left and right singular vectors
```

```
U1 = U(:,1)'
U2 = U(:,2)'
a=subplot(1,2,1)
title(a, 'Two Left Singular Vectors')
plot(1:size(U1,2), U1, '-', 1:size(U2,2), U2, '--')
xlabel('dimensional index')
ylabel('dimensional value')
legend('First Left Singular Vector', 'Second Left Singular Vector', 4)
hold on

V1 = V(:,1)'
V2 = V(:,2)'
b=subplot(1,2,2)
title(b,'Two Right Singular Vectors')
plot(1:size(V1,2), V1, '-', 1:size(V2,2), V2, '--')
xlabel('dimensional index')
ylabel('dimensional value')
legend('First Right Singular Vector', 'Second Right Singular Vector', 4)
hold on

%% 5. Plot the projected document vectors in the space
% spanned by the first two left singular vectors.
docNames = {'c1', 'c2', 'c3', 'c4', 'c5', 'm6', 'm7', 'm8', 'm9', 'm10'};
figure;
for i = 1:size(B,2),
   doc_vector = B(:,i);
   x = U1 * doc_vector;
   y = U2 * doc_vector;
   plot([x],[y],'x')
   text(x+0.005,y, docNames{i})
   hold on
end
xlabel('First Left Singular Vector')
ylabel('Second Left Singular Vector')


%% 6. Plot the projected term vectors in the space
% spanned by the first two right singular vectors.
figure;
hold on
for i = 1:size(B,1),
   term_vector = B(i,:);
   x = term_vector * V1';
   y = term_vector * V2';
   plot([x],[y],'x')
   text(x+0.005,y, keywords(i))
   hold on
end
xlabel('First Right Singular Vector')
ylabel('Second Right Singular Vector')
```