The University of Texas
at Austin

CS363D Statistical Learning and Data Mining

Homework 02

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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)

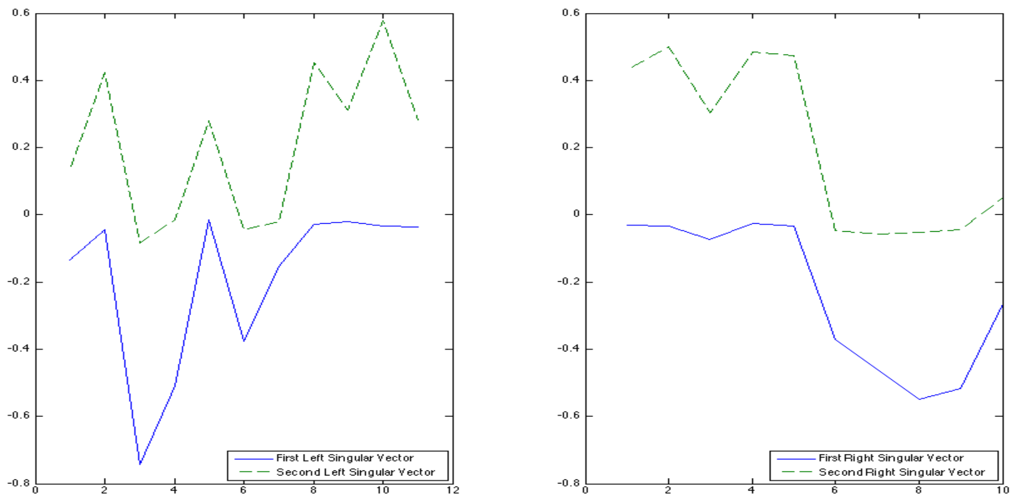

Figure 3: Two Left Columns and Right Columns

5 Plot the projected document vectors

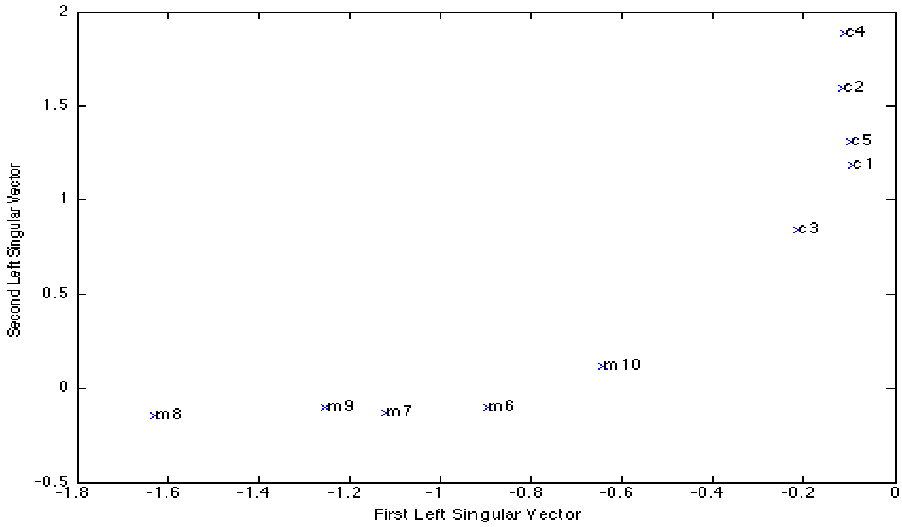

Figure 4: Projected Document Vectors

6 Plot the projected term vectors

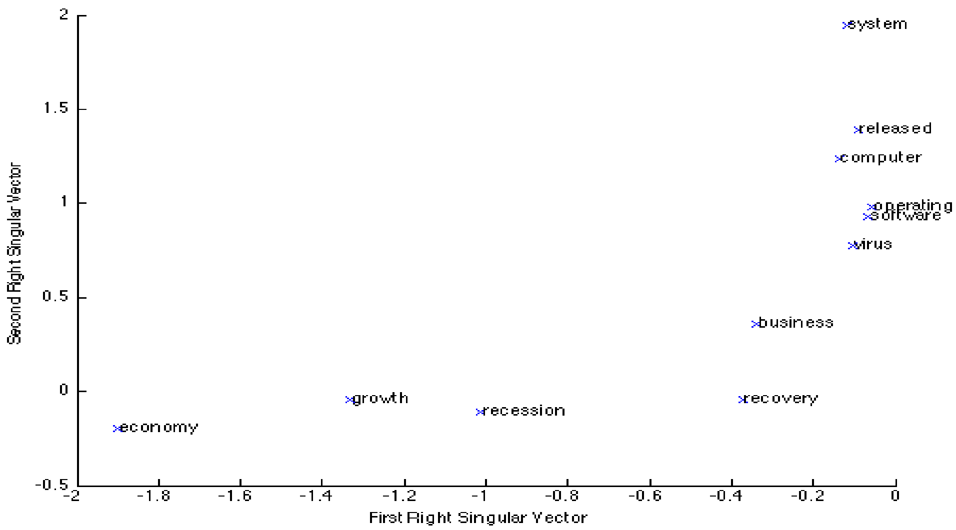

Figure 5: Projected Term Vectors

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, '--')
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, '--')
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(A,2),
   doc_vector = A(:,i);
   x = U1 * doc_vector;
   y = U2 * doc_vector;
   plot([x],[y],'.')
   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(A,1),
   term_vector = A(i,:);
   x = term_vector * V1';
   y = term_vector * V2';
   plot([x],[y],'.')
   text(x+0.005,y, keywords(i))
   hold on
end
xlabel('First Right Singular Vector')
ylabel('Second Right Singular Vector')
```