NOTE:

1. In the first step, the matrices, initial state matrix(Pi), state transition matrix(A) and probability density matrix(b) are defined.
2. Subsequently, the forward and backward algorithms are implemented to find out Alpha and Beta values.
3. Then, Baum-Welch algorithm is implemented to estimate the state transition matrix(E_A) and probability density matrix(E_B)
4. The BW algorithm is also implemented to find the no. of transitions from a particular state (E_T) and also the probabilities of transitions from each state to every state(E_I_J).
5. The probability of a node being visited is then calculated (because some of the nodes are skipped during the transition-skip jump HMM)
6. After finding the probability matrix and the status of the nodes (during transition), the normalized values of the state transition matrix(N_E_A) and the probability density matrix(N_E_B) are calculated.

FULL PROGRAM:

```
% Definitions
% global T;global N;global K;global a;global b;global Pi;global Ob;global
Beta;global Alpha;
% global i;global j;global t;global ZI;global nu;global Gamma;global
E_T;global E_I_J;global E_Pi;global N_E_A;global E_A;global E_B;global
sum1;global sum;
% global p_v;global m;global n;global status;global tt;
T = 19;
N = 6;
K = 3;
a = [0.2,0.2,0.15,0.15,0.1,0.1 ; 0,0.2,0.1,0.25,0.25,0.1 ;
0,0,0.15,0.15,0.2,0.2 ; 0,0,0,0.25,0.3,0.45 ; 0,0,0,0,0.62,0.38 ;
0,0,0,0,0,1];
b = [0.4,0.4,0.2 ; 0.25,0.45,0.3 ; 0.2,0.35,0.45 ; 0.2,0.3,0.5 ; 0.6,0.2,0.2
; 0.1,0.4,0.5];
Pi=[0.4,0.3,0.3,0,0,0];
sum=0;
Ob=[2,3,2,3,2,1,2,2,2,1,3,2,1,1,2,3,3,2,1];
Beta=zeros(T,N);
Alpha=zeros(T,N);
i=0;
j=0;
t=0;
ZI=zeros(T,N,N);
nu=0.0;
Gamma=zeros(T,N);
E_T=zeros(1,N);
E_I_J=zeros(1,N);
E_Pi=zeros(1,N);
E_A=zeros(N,N);
N_E_A=zeros(N,N);
```

```matlab
E_B=zeros(N,K);
sum1=zeros(K);
p_v=zeros(N);
status=zeros(1,N);
m=0;
n=0;
tt=0;

%Fowward Algorithm
for i=1:N
    Alpha(1,i)=Pi(i) * b(i,Ob(1));
end
for t=1:T-1
    for j=1:N
        sum=0;
        for i=1:N
            sum= sum+ Alpha(t,i)*a(i,j);
        end
        Alpha(t+1,j)=sum * b(j,Ob(t+1));
    end
end
disp('The forward matrix is:');
for i=1:T
    for j=1:N
        fprintf('%.8f',Alpha(i,j));
        fprintf('    ');
    end
    fprintf('\n');
end
fprintf('\n');

%Backward Algorithm
for i=1:N
    Beta(T,i)=1;
end
for t=T-1:-1:1
    for i=1:N
        sum=0;
        for j=1:N
            sum=sum+(a(i,j)*Beta(t+1,j)*b(j,Ob(t+1)));
        end
        Beta(t,i)=sum;
    end
end
disp('The backward matrix is:');
for i=1:T
    for j=1:N
        fprintf('%.8f',Beta(i,j));
        fprintf('    ');
    end
    fprintf('\n');
end
fprintf('\n');

%Baum-Welch Algorithm
kk=0;
```

```
sum2=0;
%Calculation of ZI values
for t=1:T-1
    for i=1:N
        for j=1:N
            nu=Alpha(t,i)*b(j,Ob(t+1))*Beta(t+1,j)*a(i,j);
            sum=0;
            for m=1:N
                for n=1:N
                    sum = sum + (Alpha(t,m) *a(m,n) *b(n,Ob(t+1))
*Beta(t+1,n));
                end
            end
            ZI(t,i,j) = nu/sum;
        end
    end
end
% disp('The ZI matrix is:');
% disp(ZI);

%Gamma computation
for t=1:T
    for i=1:N
        sum=0;
        for j=1:N
            sum = sum+ZI(t,i,j);
        end
        Gamma(t,i)=sum;
    end
end
disp('The Gamma matrix is:');
for i=1:T
    for j=1:N
        fprintf('%.8f',Gamma(i,j));
        fprintf('    ');
    end
    fprintf('\n');
end
fprintf('\n');

%Expected number of transistions from state i
for i=1:N
    sum=0;
    for t=1:T-1
        sum= sum + Gamma(t,i);
    end
    E_T(i)=sum;
end
disp('Expected no of transitions from the states:');
for i=1:N
fprintf('%.4f',E_T(i));
fprintf('\n');
end

%Expected number of transitions from node i to node j
for i=1:N
```

```
    for j=1:N
        sum=0;
        for t=1:T-1
            sum= sum+ZI(t,i,j);
        end
        E_I_J(i)=sum; % may be a mistake (already mentioned in the C
version)..............
        fprintf('\nExpected no of transitions from the state %d to state
%d:', i,j);
        fprintf('%.4f ',E_T(i));
    end
end

%Computing estimated values for Pi ,A and B.
for i=1:N
    E_Pi(i)= Gamma(1,i);    % E_Pi(i)= Gamma(0,(i));
end

for i=1:N
    for j=1:N
        sum=0;
        nu=0;
        for t=1:T-1
            sum=sum+ZI(t,i,j);
            nu=nu+Gamma(t,i);
        end
        E_A(i,j) = (sum / nu)  ;
    end
end
disp('\nThe estimated state transition matrix is:');
for i=1:N
    for j=1:N
        fprintf('%.8f',E_A(i,j));
        fprintf('    ');
    end
    fprintf('\n');
end
fprintf('\n');

%Computing the matrix B
for j=1:N     % number of states
    sum2=0;
    for kk=1:K
        sum1(kk)=0;
    end
    for t=1:T  %to traverse the observation sequence...
        for kk=1:K
            if(Ob(t) == kk)  % here one for loop will come
                sum2 = sum2+ Gamma(t,j); % overall sum .........
                sum1(kk)= sum1(kk) + Gamma(t,j);
                break;
            end
        end
    end
    for kk=1:K
        E_B(j,kk) = (sum1(kk))/sum2;
```

```
    end
end

disp('The estimated probability matrix is:');
for i=1:N
    for j=1:K
        fprintf('%.8f',E_B(i,j));
        fprintf('     ');
    end
    fprintf('\n');
end
fprintf('\n');



%probability of visit
sum = 0;
disp(' The probability of the node being visited during the training phase');
disp(N);
for i=1:N
    if(i==1)
        p_v(i)=E_Pi(i);
    else
        sum=0;
        for j=1:(i-1)
            sum= sum + p_v(j)*(E_A(j,i)/(1-E_A(j,j)) );
        end
    end
    p_v(i)= sum + (E_Pi(i));
end

tt=1;
for i=1:N
    if(p_v(i)*100 >= 40.0)
        status(tt)=i;
        tt= tt +1;
    else
        status(i)=0;
    end
end
disp('Thee status during the transition is:');
disp(status);
fprintf('\n');




%Normalization
sum2 = 0;
sum3 = 0;
pp = 0;
pp1 = 0;
for i=1:N
    if(i==status(pp+1)) % status(pp)
        pp=pp+1;
        for j=1:N
            N_E_A(i,j)=E_A(i,j);
```

```
        end
    else
        sum3=0;
        sum2=0;
        pp1=0;
        for j=1:N
            if(j==status(pp1+1)) %status(pp1)
                pp1=pp1+1;
                sum3= sum3 + a(i,j);
            else
                sum2= sum2 + E_A(i,j);
            end
        end

        pp1=0;
        for j=1:N
            if(j~=status(pp1+1))  %status(pp1)
                N_E_A(i,j)=(1-sum3)*(E_A(i,j)/sum2);
            else
                pp1=pp1+1;
                N_E_A(i,j)=a(i,j);
            end
        end
    end
end
disp('After Normalization:');
fprintf('\n');
disp('The estimated state transition matrix is:');
for i=1:N
    for j=1:N
        fprintf('%.8f',E_A(i,j));
        fprintf('     ');
    end
    fprintf('\n');
end
fprintf('\n');
disp('The estimated probability matrix is:');
for i=1:N
    for j=1:K
        fprintf('%.8f',E_B(i,j));
        fprintf('     ');
    end
    fprintf('\n');
end
```

OUTPUT

>> HMM

The forward matrix is:

0.16000000	0.13500000	0.10500000	0.00000000	0.00000000	0.00000000
0.00640000	0.01770000	0.02396250	0.03675000	0.01415000	0.02525000
0.00051200	0.00216900	0.00221353	0.00545006	0.00593110	0.02174680
0.00002048	0.00016086	0.00028158	0.00115680	0.00126969	0.01358198
0.00000164	0.00001632	0.00002149	0.00011242	0.00024657	0.00586379
0.00000013	0.00000090	0.00000102	0.00000713	0.00011708	0.00060142
0.00000001	0.00000009	0.00000009	0.00000065	0.00001503	0.00025977
0.00000000	0.00000001	0.00000001	0.00000006	0.00000191	0.00010632
0.00000000	0.00000000	0.00000000	0.00000001	0.00000024	0.00004283
0.00000000	0.00000000	0.00000000	0.00000000	0.00000009	0.00000429
0.00000000	0.00000000	0.00000000	0.00000000	0.00000001	0.00000216
0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000087
0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000009
0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000001
0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000

The backward matrix is:

0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000

0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
0.00000001	0.00000001	0.00000001	0.00000001	0.00000001	0.00000001
0.00000005	0.00000004	0.00000003	0.00000004	0.00000003	0.00000005
0.00000021	0.00000017	0.00000010	0.00000014	0.00000012	0.00000013
0.00000088	0.00000078	0.00000045	0.00000058	0.00000060	0.00000032
0.00000323	0.00000311	0.00000199	0.00000273	0.00000389	0.00000080
0.00001432	0.00001492	0.00000981	0.00001272	0.00000965	0.00000800
0.00006300	0.00006428	0.00003733	0.00004737	0.00005331	0.00001600
0.00017797	0.00022943	0.00016197	0.00023093	0.00038089	0.00004000
0.00058256	0.00064767	0.00048051	0.00071960	0.00098304	0.00040000
0.00217854	0.00203603	0.00166478	0.00274963	0.00223397	0.00400000
0.00582824	0.00625181	0.00518025	0.00805553	0.00575783	0.01000000
0.01913624	0.01997200	0.01457454	0.02086553	0.01578896	0.02000000
0.08107500	0.07732500	0.04727500	0.06322500	0.06604000	0.04000000
0.26000000	0.28000000	0.20000000	0.27500000	0.41000000	0.10000000
1.00000000	1.00000000	1.00000000	1.00000000	1.00000000	1.00000000

The Gamma matrix is:

0.38859880	0.35611230	0.25528890	0.00000000	0.00000000	0.00000000
0.04848167	0.12226910	0.12661825	0.31091834	0.09811092	0.29360172
0.01130690	0.05044071	0.03965859	0.14612607	0.12029961	0.63216811
0.00183240	0.01336520	0.01487677	0.08570761	0.09457612	0.78964190
0.00050190	0.00478682	0.00440358	0.03383842	0.10418316	0.85228612
0.00019251	0.00103594	0.00077030	0.00825351	0.11560487	0.87414288
0.00006397	0.00045396	0.00025946	0.00255381	0.05274895	0.94391984

0.00002084	0.00020572	0.00010943	0.00100227	0.03280888	0.96585286
0.00000615	0.00008029	0.00004647	0.00043963	0.02670176	0.97272570
0.00000218	0.00002071	0.00001249	0.00012837	0.02496211	0.97487414
0.00000038	0.00000594	0.00000592	0.00007304	0.01713765	0.98277706
0.00000009	0.00000203	0.00000193	0.00003002	0.01522257	0.98474336
0.00000002	0.00000030	0.00000026	0.00000526	0.01464083	0.98535332
0.00000001	0.00000005	0.00000004	0.00000112	0.01238028	0.98761850
0.00000000	0.00000002	0.00000001	0.00000027	0.00395686	0.99604284
0.00000000	0.00000000	0.00000000	0.00000010	0.00134548	0.99865441
0.00000000	0.00000000	0.00000000	0.00000004	0.00069786	0.99930210
0.00000000	0.00000000	0.00000000	0.00000001	0.00053725	0.99946273
0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000

Expected no of transitions from the states:

0.4510

0.5488

0.4421

0.5891

0.7359

15.2332

Expected no of transitions from the state 1 to state 1:0.4510

Expected no of transitions from the state 1 to state 2:0.4510

Expected no of transitions from the state 1 to state 3:0.4510

Expected no of transitions from the state 1 to state 4:0.4510

Expected no of transitions from the state 1 to state 5:0.4510

Expected no of transitions from the state 1 to state 6:0.4510

Expected no of transitions from the state 2 to state 1:0.5488

Expected no of transitions from the state 2 to state 2:0.5488

Expected no of transitions from the state 2 to state 3:0.5488

Expected no of transitions from the state 2 to state 4:0.5488

Expected no of transitions from the state 2 to state 5:0.5488

Expected no of transitions from the state 2 to state 6:0.5488

Expected no of transitions from the state 3 to state 1:0.4421

Expected no of transitions from the state 3 to state 2:0.4421

Expected no of transitions from the state 3 to state 3:0.4421

Expected no of transitions from the state 3 to state 4:0.4421

Expected no of transitions from the state 3 to state 5:0.4421

Expected no of transitions from the state 3 to state 6:0.4421

Expected no of transitions from the state 4 to state 1:0.5891

Expected no of transitions from the state 4 to state 2:0.5891

Expected no of transitions from the state 4 to state 3:0.5891

Expected no of transitions from the state 4 to state 4:0.5891

Expected no of transitions from the state 4 to state 5:0.5891

Expected no of transitions from the state 4 to state 6:0.5891

Expected no of transitions from the state 5 to state 1:0.7359

Expected no of transitions from the state 5 to state 2:0.7359

Expected no of transitions from the state 5 to state 3:0.7359

Expected no of transitions from the state 5 to state 4:0.7359

Expected no of transitions from the state 5 to state 5:0.7359

Expected no of transitions from the state 5 to state 6:0.7359

Expected no of transitions from the state 6 to state 1:15.2332

Expected no of transitions from the state 6 to state 2:15.2332

Expected no of transitions from the state 6 to state 3:15.2332

Expected no of transitions from the state 6 to state 4:15.2332

Expected no of transitions from the state 6 to state 5:15.2332

Expected no of transitions from the state 6 to state 6:15.2332

The estimated state transition matrix is:

0.13837680	0.18400028	0.14456647	0.24935409	0.05727776	0.22642460
0.00000000	0.19986409	0.09095286	0.37079337	0.14391730	0.19447238
0.00000000	0.00000000	0.16208460	0.25492530	0.14193055	0.44105956
0.00000000	0.00000000	0.00000000	0.27236339	0.20597941	0.52165720
0.00000000	0.00000000	0.00000000	0.00000000	0.60810330	0.39189670
0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	1.00000000

The estimated probability matrix is:

0.00043175	0.88800822	0.11156004
0.00192610	0.75090661	0.24716729
0.00177150	0.67812855	0.32009995
0.01423964	0.31233646	0.67342390
0.22772746	0.48437519	0.28789735
0.25089915	0.48231607	0.26678478

The probability of the node being visited during the training phase

6

Thee status during the transition is:

2 4 6 0 0 0

After Normalization:

The estimated state transition matrix is:

0.13837680	0.18400028	0.14456647	0.24935409	0.05727776	0.22642460
0.00000000	0.19986409	0.09095286	0.37079337	0.14391730	0.19447238
0.00000000	0.00000000	0.16208460	0.25492530	0.14193055	0.44105956
0.00000000	0.00000000	0.00000000	0.27236339	0.20597941	0.52165720
0.00000000	0.00000000	0.00000000	0.00000000	0.60810330	0.39189670
0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	1.00000000

The estimated probability matrix is:

0.00043175	0.88800822	0.11156004
0.00192610	0.75090661	0.24716729
0.00177150	0.67812855	0.32009995
0.01423964	0.31233646	0.67342390
0.22772746	0.48437519	0.28789735
0.25089915	0.48231607	0.26678478