**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);

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