```
t = 1:5;
s = t;
% by cols: 6 locations, by rows: 5 time
X = [1.0095,0.0095,0,0,0,0;0.9634,1.9649,0.0015,0,0,0;0,0.0001,1.0006,0.0005,0,0;0,0,0.0002,1.8
```

```
X = 5×6
    1.0095    0.0095         0         0         0         0
    0.9634    1.9649    0.0015         0         0         0
         0    0.0001    1.0006    0.0005         0         0
         0         0    0.0002    1.8680    0.8678         0
         0         0         0    0.0362    1.1570    0.1207
```

```
P = X';%6*5
V= P(1:5,:);
b = V;
dX = V;

w0 = P(1,:);
O = P(1:4,:);
D = P(2:5,:);
M = 6;
const = 0.57721;
Sum = 100000;
%fix beta and change alpha, c = mu - beta*log(-log(p))+const
betah = 0.1:0.8; %high-noise
betal = 1:30; %low-noise
beta = 0.5 %simulation
```

```
beta = 0.5000
```

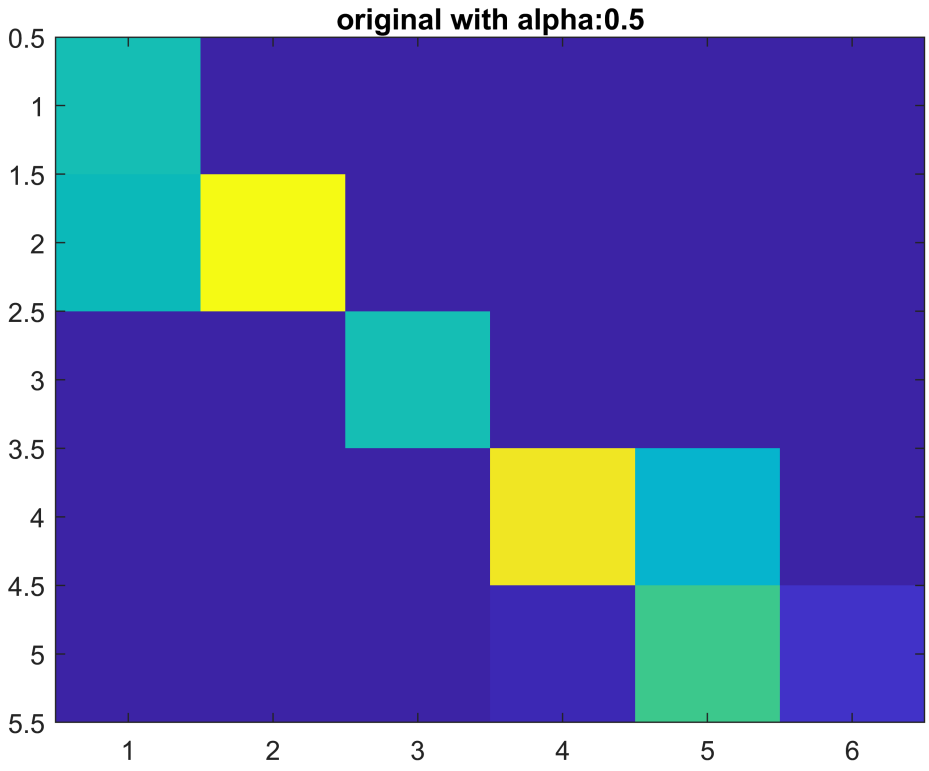
```
% determine k and eps with deterministic model
W = exp(-w0.^2/2)/sqrt(2*pi*1);
mu = mean(P(1,:));
sigma = var(P(1,:));
B = exp(mu-sigma^2*t/2+sigma*W);
W1 = exp(-P(2,:).^2/2)/sqrt(2*pi*1);
mu1 = mean(P(2,:));
sigma1 = var(P(2,:));
B1 = exp(mu1-sigma1^2*t/2+sigma1*W1);
k = sigma*B./W-1;
% W1 -W = eps1*W1*(D(1,:)-k*W(1,:))+sigma1*W1*(B1-B)
eps1 = (W1-W-sigma1*W1.*(B1-B))./W1./(D(1,:)-k.*W(1,:));
eps = mean(eps1);
% learning rate
delta = 0.1;
% learning rate for potential function of cost
gamma = 100;
% initial threshold
Sum = 100;
sc = 1;
% optimize the cost and predict
for alpha = [0.5,1,1.5,2]
    for i = 1:M-1
        if i ==1
            for j = 2:M-1
```

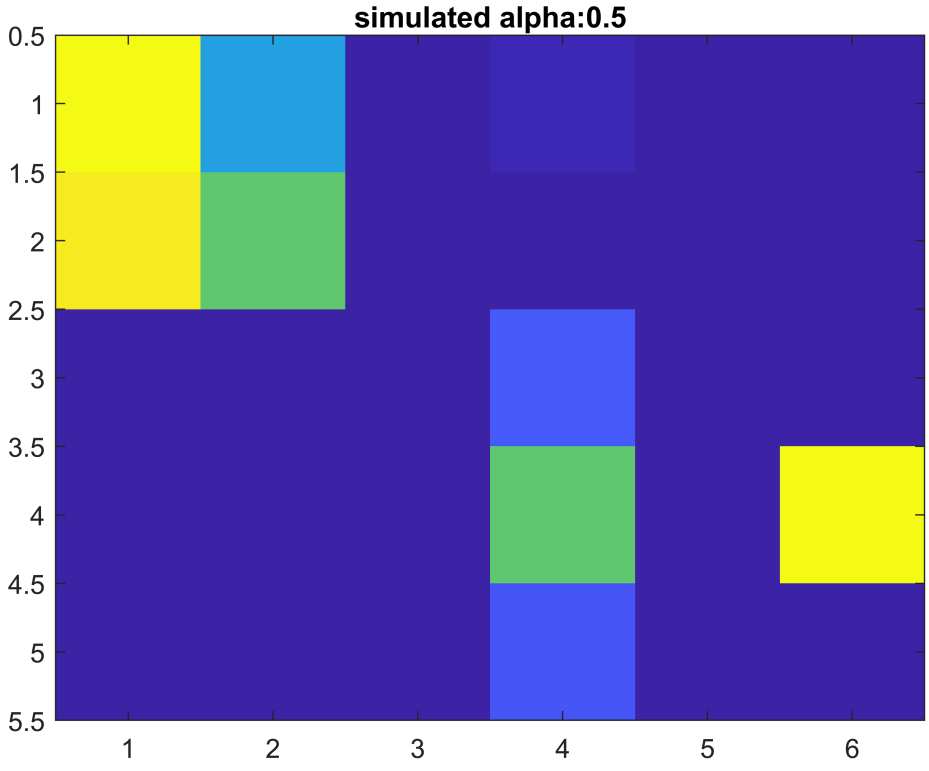
```
            for t = 1:5
                if t == 1
                    mui = P(j,1);
                    vari = P(j,1);
                    c = mui - beta*log(-log(normpdf(mui)))+const
                    %cost
                    W = exp(-P(i,:).^2/2)/sqrt(2*pi*1);
                    V(i,t) = -eps*(1/alpha*sum(O(i,1).*log(exp(alpha*P(j,1)-beta*c))))+sum(
                    %brownian
                    b(i,t) = exp(mui-vari*t/2+std(P(j,1:t))*W(t));
                else
                    mui = mean(P(j,1:t));
                    vari = var(P(j,1:t));
                    c = mui - beta*log(-log(normpdf(mui)))+const
                    W = exp(-P(j,:).^2/2)/sqrt(2*pi*1);
                    V(i,t) = sum(-eps*(1/alpha*sum(O(i,t)*log(sum(exp(alpha*P(j,1:t)-beta*c
                    b(i,t) = exp(mui-vari*t/2+std(P(j,t))*W(t));
                end
            end
        end
        dX(i,:)=(-V(i,:)+sqrt(vari)*b(i,:));
    elseif i<M-1
        for j  = [1:i-1,i+1:M-1]
            for t = 1:5
                if t == 1
                    mui = P(j,1);
                    vari = P(j,1:t);
                    c = mui - beta*log(-log(normpdf(mui)))+const
                    W = exp(-P(j,:).^2/2)/sqrt(2*pi*1);
                    V(i,t) = -eps*(1/alpha*(O(i,t).*log(exp(alpha*P(j,t)-beta*c))))+k(j)*ex
                    b(i,t) = exp(mui-vari*t/2+std(P(j,1:t))*W(t));
                else
                    mui = mean(X(j,1:t));
                    vari = var(X(j,1:t));
                    c = mui - beta*log(-log(normpdf(mui)))+const
                    W = exp(-P(j,:).^2/2)/sqrt(2*pi*1);
                    V(i,t) = -eps*(1/alpha*(O(i,t).*log(exp(alpha*P(j,t)-beta*c))))+k(j)*ex
                    b(i,t) = exp(mui-vari*t/2+std(P(j,1:t))*W(t));
                end
            end
        end
    elseif i == M-1
        for j  = [1:i-1]
            for t = 1:5
                if t == 1
                    mui = P(j,1);
                    vari = P(j,1:t);
                    c = mui - beta*log(-log(normpdf(mui)))+const
                    W = exp(-P(j,:).^2/2)/sqrt(2*pi*1);
                    V(i,t) = -eps*(1/alpha*(O(i-1,t).*log(exp(alpha*P(j,t)-beta*c))))+k(j)*
                    b(i,t) = exp(mui-vari*t/2+std(P(j,1:t))*W(t));
                else
                    mui = mean(X(j,1:t));
                    vari = var(X(j,1:t));
```

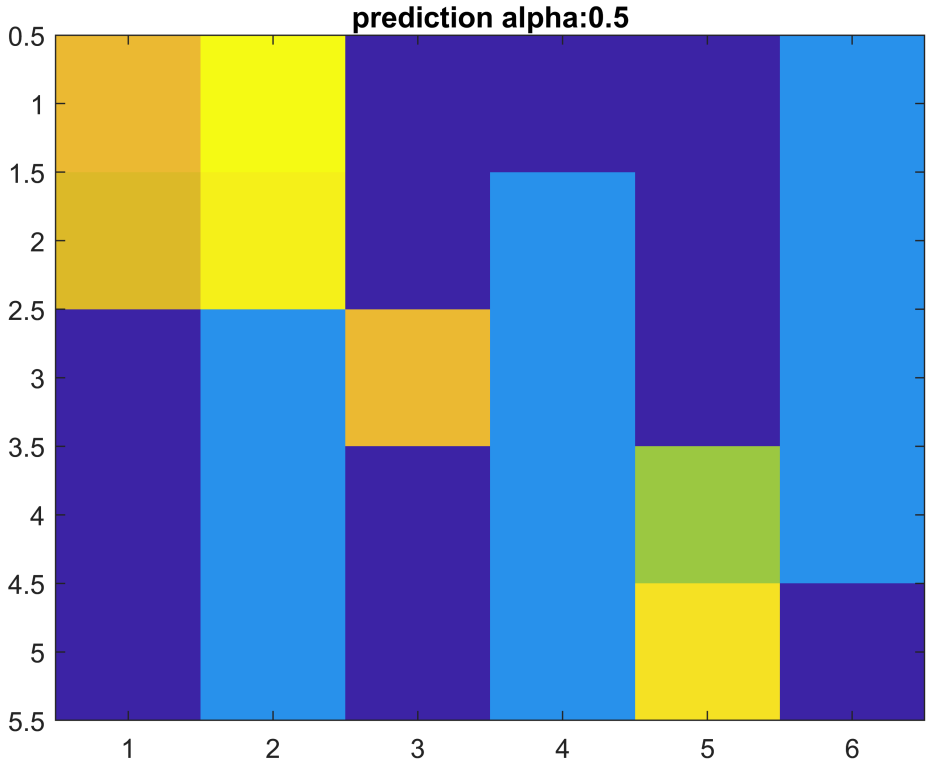
```
                        c = mui - beta*log(-log(normpdf(mui)))+const
                        W = exp(-P(j,:).^2/2)/sqrt(2*pi*1);
                        V(i,t) = -eps*(1/alpha*(O(i-1,t).*log(exp(alpha*P(j,t)-beta*c))))+k(j)*
                        b(i,t) = exp(mui-vari*t/2+std(P(j,1:t))*W(t));
                    end
                end
            end
            %predict the stochastic dynamics
            dX(i,:)=(-V(i,:)+sqrt(vari)*b(i,:));
        end
    end
    Xhat = X;%What = exp(Xhat);
    %prediction simulated
    Y = Xhat;
    Yhat = zeros(5,100,6);
    %Bayes prediiction
    for dt = 1:5
        for steps = 1: 100
    %    Xhat(1+dt,:) = X(dt,:) + dX(dt,:)/sum(dX(dt,:));
            Xhat(:,1+dt) = dX(:,dt).*exp(-gamma*V(:,dt))+P(1+dt,:)' + dX(:,dt)./sum(dX(:,dt));
            Xhat(Xhat(:,1+dt)<0,1+dt) = 0.000001;
            %normalization
            Xhat(:,1+dt) = Xhat(:,1+dt)./sum(Xhat(:,1+dt));
            if sum(sum(abs(Xhat(:,1+dt) - P(1+dt,:)'))) < Sum
                Y(:,1+dt) = Xhat(:,dt) + normpdf(Xhat(:,dt),0,1);
                Mu = mean(Xhat(:,dt));
                Sigma = std(Xhat(:,dt));
                Yhat(:,steps,1+dt) = normpdf(Xhat(:,dt),Mu,Sigma)+ normpdf(Xhat(:,dt),0,1);
                Yhat(isnan(Yhat(:,steps,1+dt)),steps, 1+dt)  = 0 ;
            end
        end
    end
    display(alpha)
    display(Xhat)

    figure,
    imagesc(X);
    title(['original with alpha:',num2str(alpha)])
    figure,
    imagesc(Xhat);
    title(['simulated alpha:',num2str(alpha)])
    figure,
    imagesc(Y);
    title(['prediction alpha:',num2str(alpha)])
    Interp = reshape(Yhat(sc,:,:),6,100);
    figure,
    imagesc(sqrt(Interp'*Interp));
    title(['interpolated simulationalpha:',num2str(alpha)])
    figure,
    imagesc(abs(Xhat-X));
    title(['residule alpha:',num2str(alpha)])
    sc = sc +1;
end
```

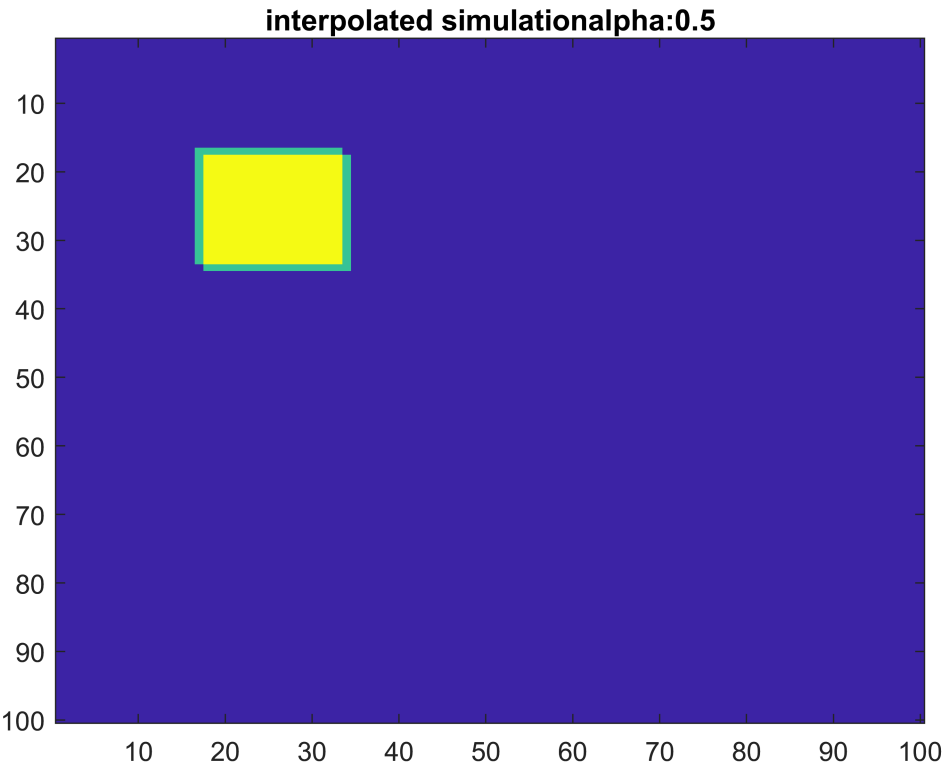
```
c = 0.6290
c = 1.3940
c = 1.1718
c = 1.0509
c = 0.9737
c = 0.6195
c = 0.6202
c = 0.9240
c = 0.8533
c = 0.8091
c = 0.6195
c = 0.6195
c = 0.6196
c = 1.0305
c = 0.9624
c = 0.6195
c = 0.6195
c = 0.6195
c = 0.8238
c = 0.9817
c = 1.4084
c = 1.0629
c = 0.9287
c = 0.8569
c = 0.8121
c = 0.6195
c = 0.6195
c = 0.9237
c = 0.8530
c = 0.8089
c = 0.6195
c = 0.6195
c = 0.6195
c = 1.0304
c = 1.0912
c = 0.6195
c = 0.6195
c = 0.6195
c = 0.6285
c = 0.8429
c = 1.4084
c = 1.0629
c = 0.9287
c = 0.8569
c = 0.8121
c = 0.6290
c = 1.6971
c = 1.3871
c = 1.2239
c = 1.1198
c = 0.6195
c = 0.6195
c = 0.6195
c = 1.0304
c = 1.0912
c = 0.6195
c = 0.6195
c = 0.6195
c = 0.6285
c = 0.8429
c = 1.4084
c = 1.0629
c = 0.9287
c = 0.8569
```

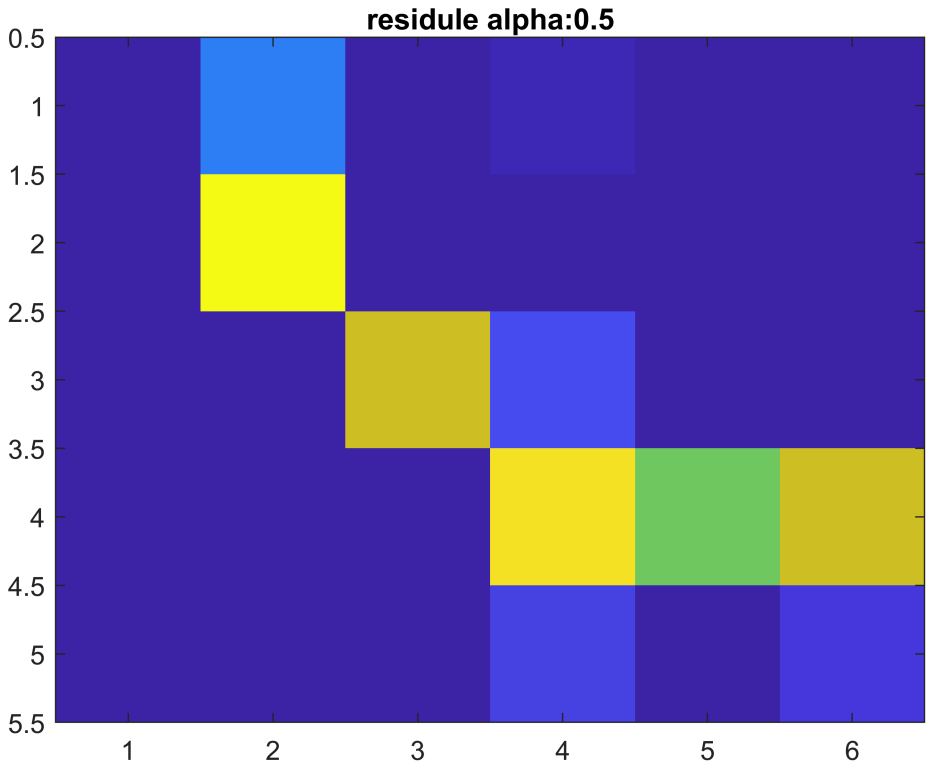
```
c = 0.8121
c = 0.6290
c = 1.6971
c = 1.3871
c = 1.2239
c = 1.1198
c = 0.6195
c = 0.6195
c = 0.9237
c = 0.8530
c = 0.8089
c = 0.6195
c = 0.6195
c = 0.6195
c = 0.6285
c = 0.8429
c = 1.4084
c = 1.0629
c = 0.9287
c = 0.8569
c = 0.8121
c = 0.6290
c = 1.6971
c = 1.3871
c = 1.2239
c = 1.1198
c = 0.6195
c = 0.6195
c = 0.9237
c = 0.8530
c = 0.8089
c = 0.6195
c = 0.6195
c = 0.6195
c = 1.0304
c = 1.0912
alpha = 0.5000
Xhat = 5×6
    1.0095    0.3641       NaN    0.0219         0    0.0000
    0.9634    0.6358         0    0.0001         0         0
         0    0.0000         0    0.1776         0         0
         0         0         0    0.6367         0    1.0000
         0    0.0000         0    0.1637       NaN    0.0000
```


original with alpha:0.5
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
5.5
1
2
3
4
5
6


simulated alpha:0.5
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
5.5
1
2
3
4
5
6


prediction alpha:0.5
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
5.5
1
2
3
4
5
6

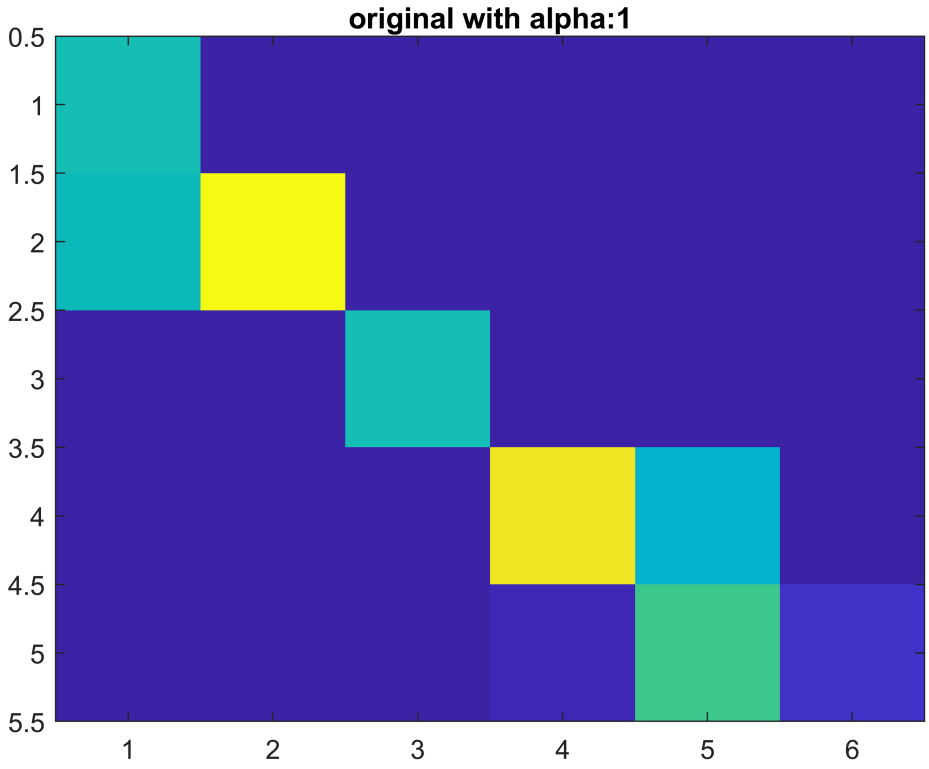

interpolated simulationalpha:0.5
10
20
30
40
50
60
70
80
90
100
10
20
30
40
50
60
70
80
90
100

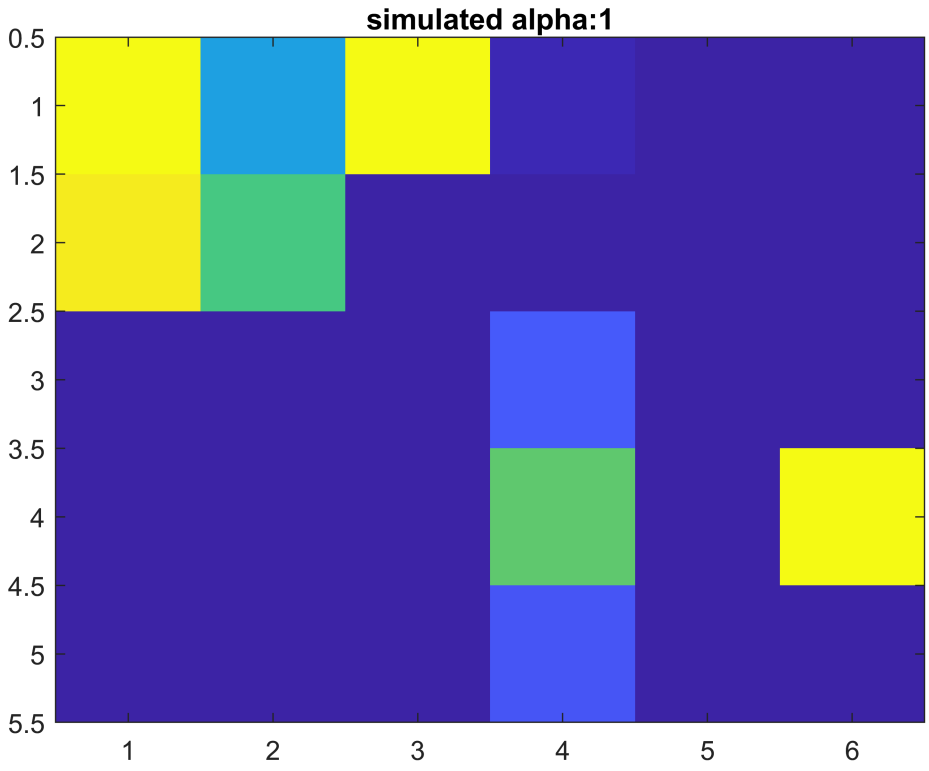


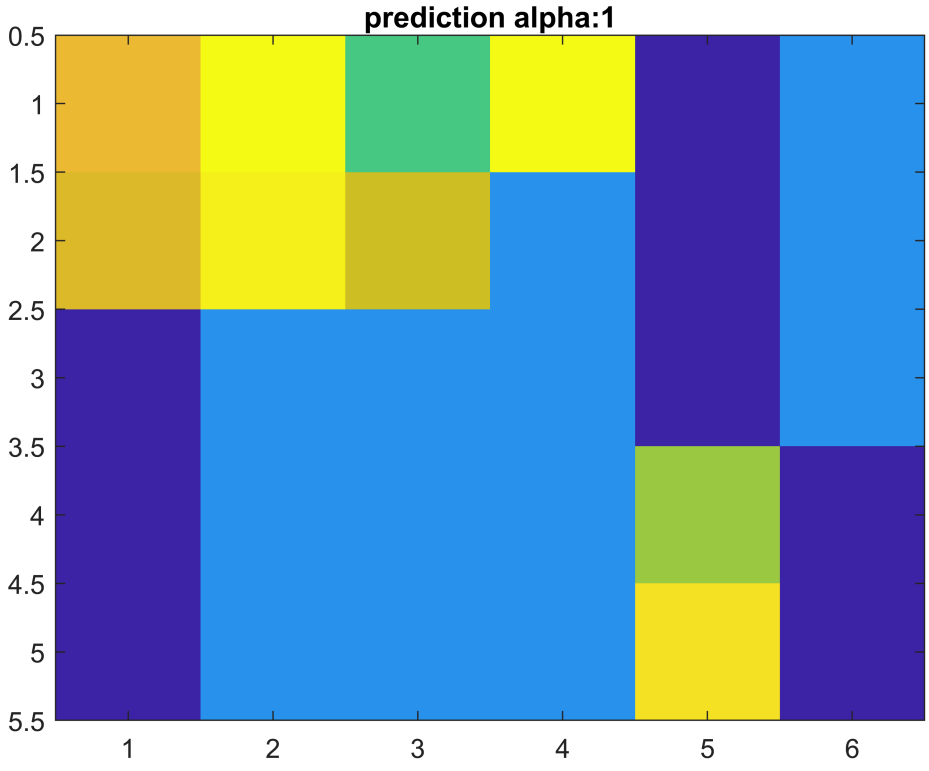

```
c = 0.6290
c = 1.3940
c = 1.1718
c = 1.0509
c = 0.9737
c = 0.6195
c = 0.6202
c = 0.9240
c = 0.8533
c = 0.8091
c = 0.6195
c = 0.6195
c = 0.6196
c = 1.0305
c = 0.9624
c = 0.6195
c = 0.6195
c = 0.6195
c = 0.8238
c = 0.9817
c = 1.4084
c = 1.0629
c = 0.9287
c = 0.8569
c = 0.8121
c = 0.6195
c = 0.6195
c = 0.9237
c = 0.8530
c = 0.8089
c = 0.6195
c = 0.6195
c = 0.6195
c = 1.0304
c = 1.0912
```

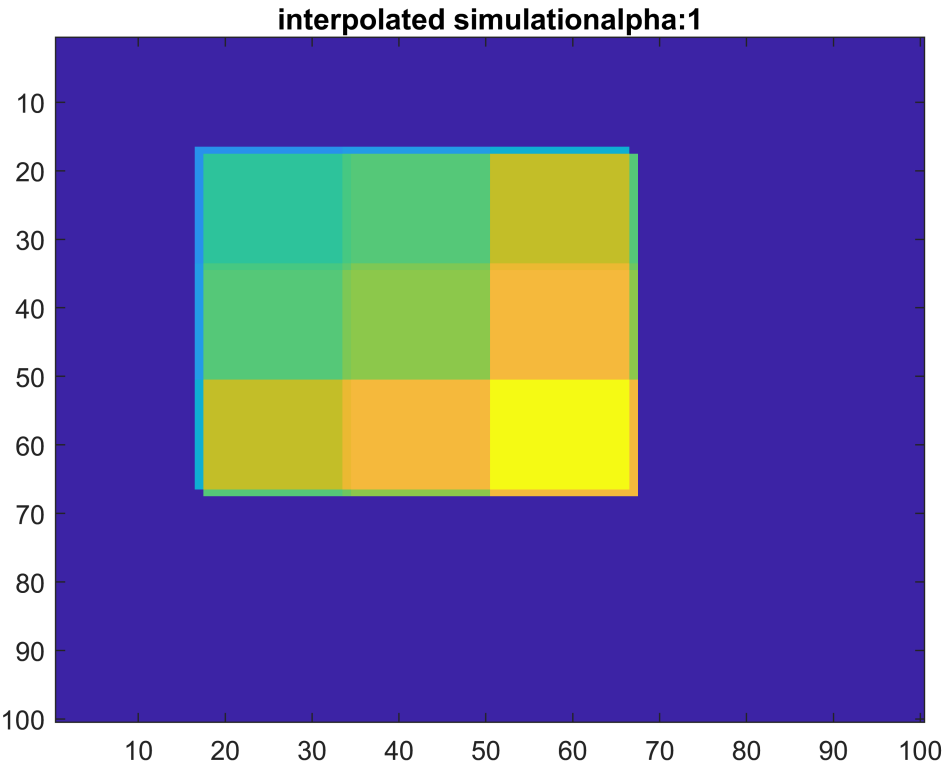
```
c = 0.6195
c = 0.6195
c = 0.6195
c = 0.6285
c = 0.8429
c = 1.4084
c = 1.0629
c = 0.9287
c = 0.8569
c = 0.8121
c = 0.6290
c = 1.6971
c = 1.3871
c = 1.2239
c = 1.1198
c = 0.6195
c = 0.6195
c = 0.6195
c = 1.0304
c = 1.0912
c = 0.6195
c = 0.6195
c = 0.6195
c = 0.6285
c = 0.8429
c = 1.4084
c = 1.0629
c = 0.9287
c = 0.8569
c = 0.8121
c = 0.6290
c = 1.6971
c = 1.3871
c = 1.2239
c = 1.1198
c = 0.6195
c = 0.6195
c = 0.9237
c = 0.8530
c = 0.8089
c = 0.6195
c = 0.6195
c = 0.6195
c = 0.6285
c = 0.8429
c = 1.4084
c = 1.0629
c = 0.9287
c = 0.8569
c = 0.8121
c = 0.6290
c = 1.6971
c = 1.3871
c = 1.2239
c = 1.1198
c = 0.6195
c = 0.6195
c = 0.9237
c = 0.8530
c = 0.8089
c = 0.6195
c = 0.6195
c = 0.6195
c = 1.0304
c = 1.0912
```

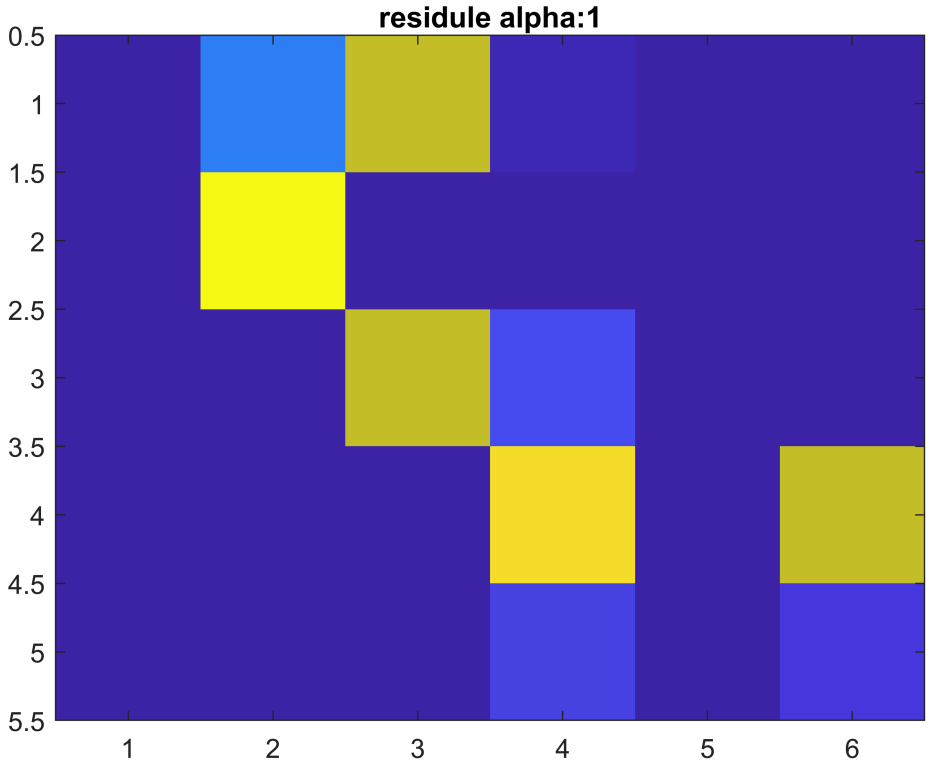
```
alpha = 1
Xhat = 5×6
    1.0095    0.3852    1.0000    0.0218         0    0.0000
    0.9634    0.6148    0.0000    0.0001         0         0
         0    0.0000    0.0000    0.1771         0         0
         0         0    0.0000    0.6355       NaN    1.0000
         0    0.0000    0.0000    0.1654       NaN    0.0000
```




simulated alpha:1
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
5.5
1
2
3
4
5
6


prediction alpha:1
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
5.5
1
2
3
4
5
6

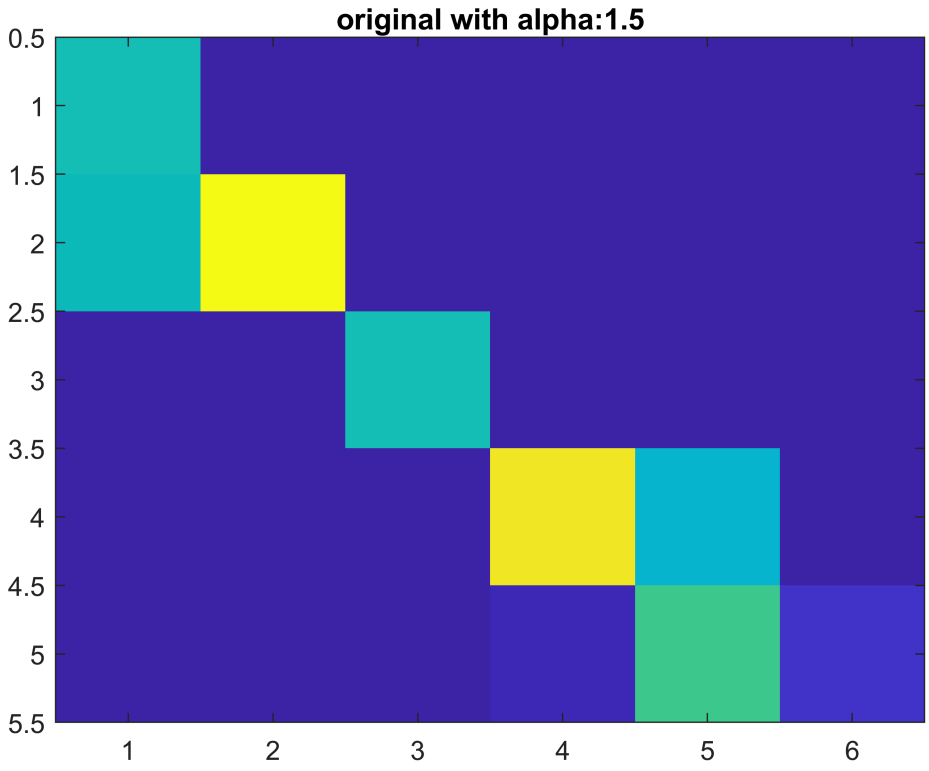


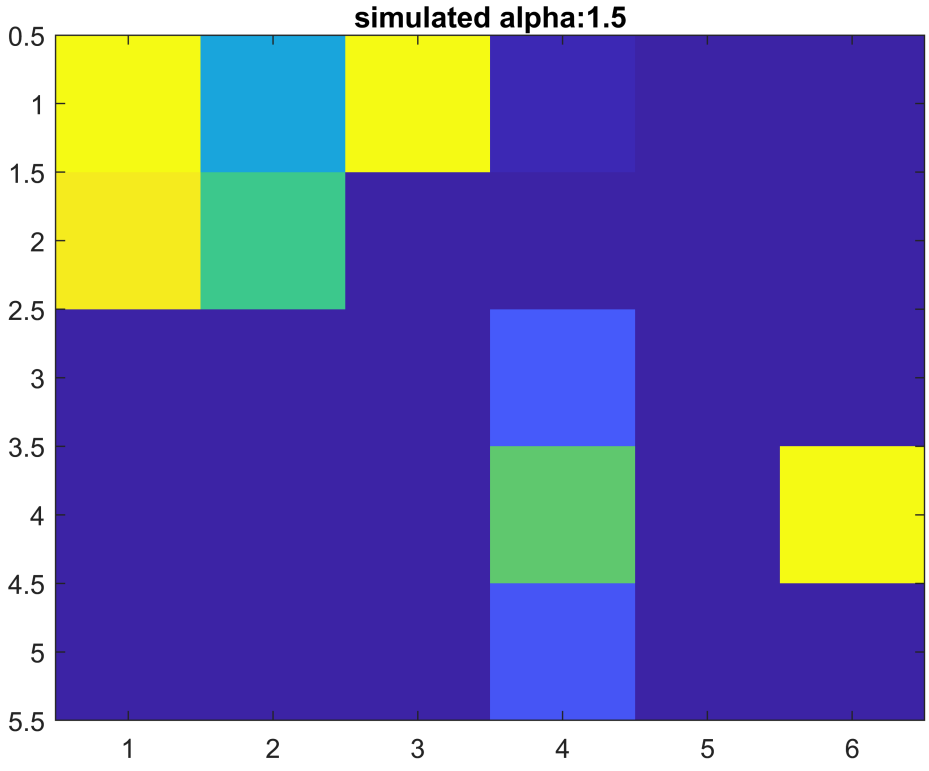


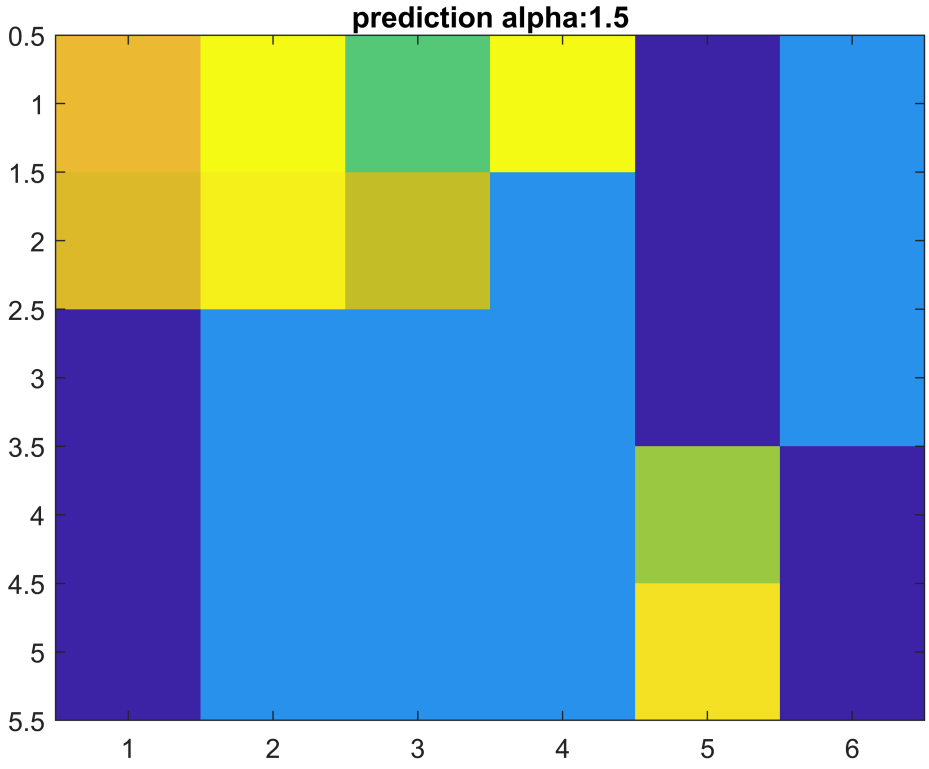

```
c = 0.6290
c = 1.3940
c = 1.1718
c = 1.0509
c = 0.9737
c = 0.6195
```

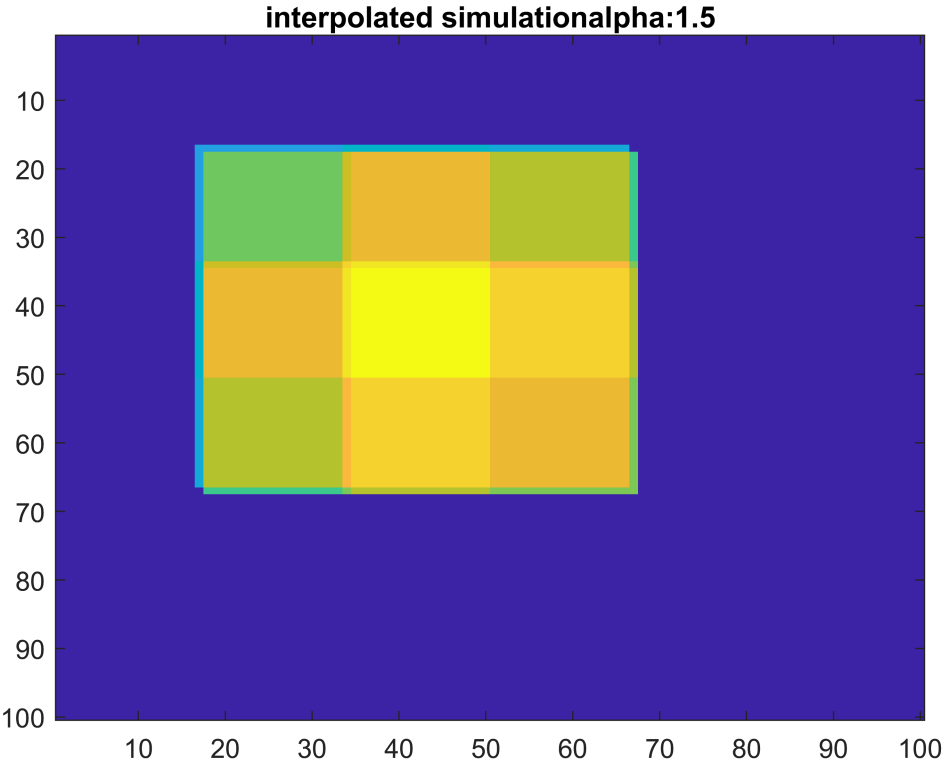
```
c = 0.6202
c = 0.9240
c = 0.8533
c = 0.8091
c = 0.6195
c = 0.6195
c = 0.6196
c = 1.0305
c = 0.9624
c = 0.6195
c = 0.6195
c = 0.6195
c = 0.8238
c = 0.9817
c = 1.4084
c = 1.0629
c = 0.9287
c = 0.8569
c = 0.8121
c = 0.6195
c = 0.6195
c = 0.9237
c = 0.8530
c = 0.8089
c = 0.6195
c = 0.6195
c = 0.6195
c = 1.0304
c = 1.0912
c = 0.6195
c = 0.6195
c = 0.6195
c = 0.6285
c = 0.8429
c = 1.4084
c = 1.0629
c = 0.9287
c = 0.8569
c = 0.8121
c = 0.6290
c = 1.6971
c = 1.3871
c = 1.2239
c = 1.1198
c = 0.6195
c = 0.6195
c = 0.6195
c = 1.0304
c = 1.0912
c = 0.6195
c = 0.6195
c = 0.6195
c = 0.6285
c = 0.8429
c = 1.4084
c = 1.0629
c = 0.9287
c = 0.8569
c = 0.8121
c = 0.6290
c = 1.6971
c = 1.3871
c = 1.2239
c = 1.1198
c = 0.6195
```

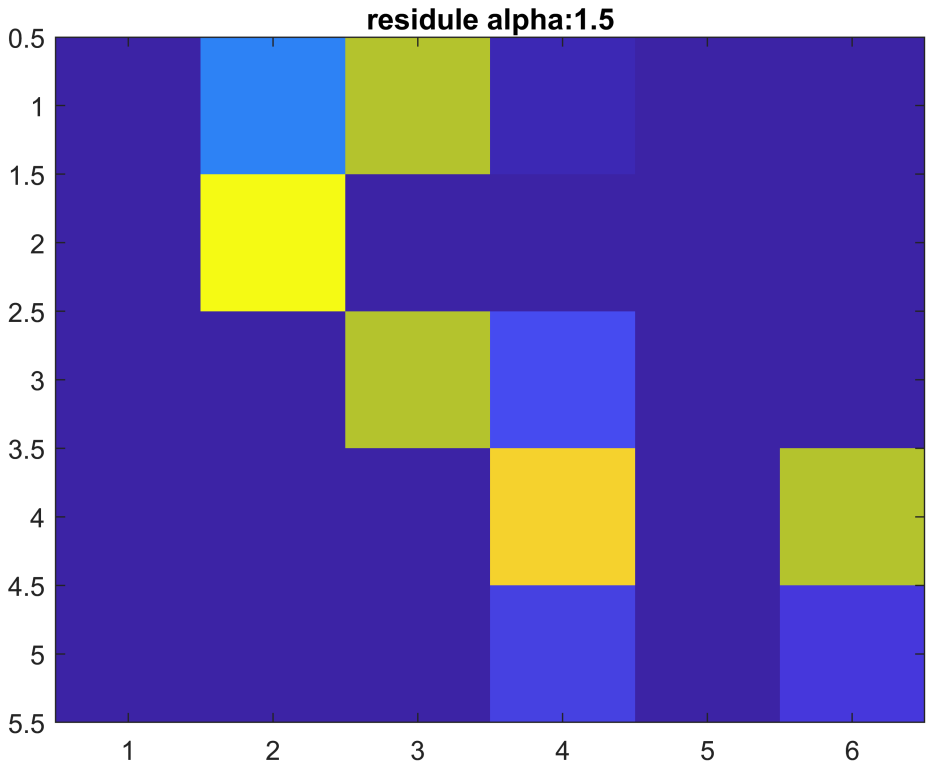
```
c = 0.6195
c = 0.9237
c = 0.8530
c = 0.8089
c = 0.6195
c = 0.6195
c = 0.6195
c = 0.6285
c = 0.8429
c = 1.4084
c = 1.0629
c = 0.9287
c = 0.8569
c = 0.8121
c = 0.6290
c = 1.6971
c = 1.3871
c = 1.2239
c = 1.1198
c = 0.6195
c = 0.6195
c = 0.9237
c = 0.8530
c = 0.8089
c = 0.6195
c = 0.6195
c = 0.6195
c = 1.0304
c = 1.0912
alpha = 1.5000
Xhat = 5×6
    1.0095    0.4033    1.0000    0.0218         0    0.0000
    0.9634    0.5966    0.0000    0.0001         0         0
         0    0.0000    0.0000    0.1769         0         0
         0         0    0.0000    0.6351       NaN    1.0000
         0    0.0000    0.0000    0.1660       NaN    0.0000
```


original with alpha:1.5
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
5.5
1
2
3
4
5
6


simulated alpha:1.5
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
5.5
1
2
3
4
5
6


prediction alpha:1.5
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
5.5
1
2
3
4
5
6

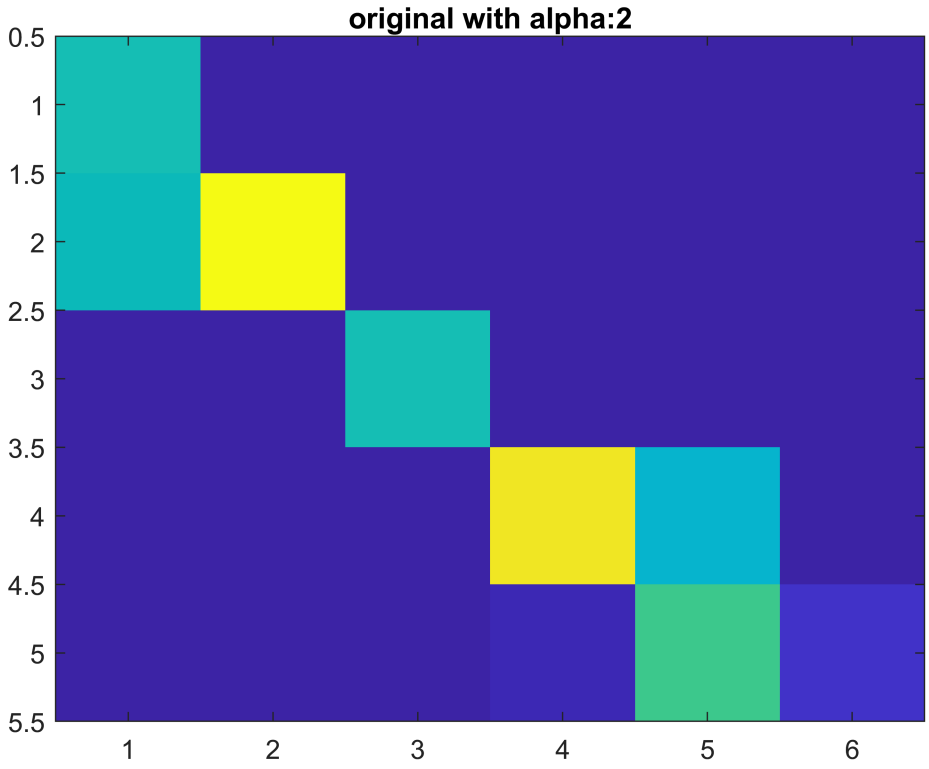

interpolated simulationalpha:1.5
10
20
30
40
50
60
70
80
90
100
10
20
30
40
50
60
70
80
90
100

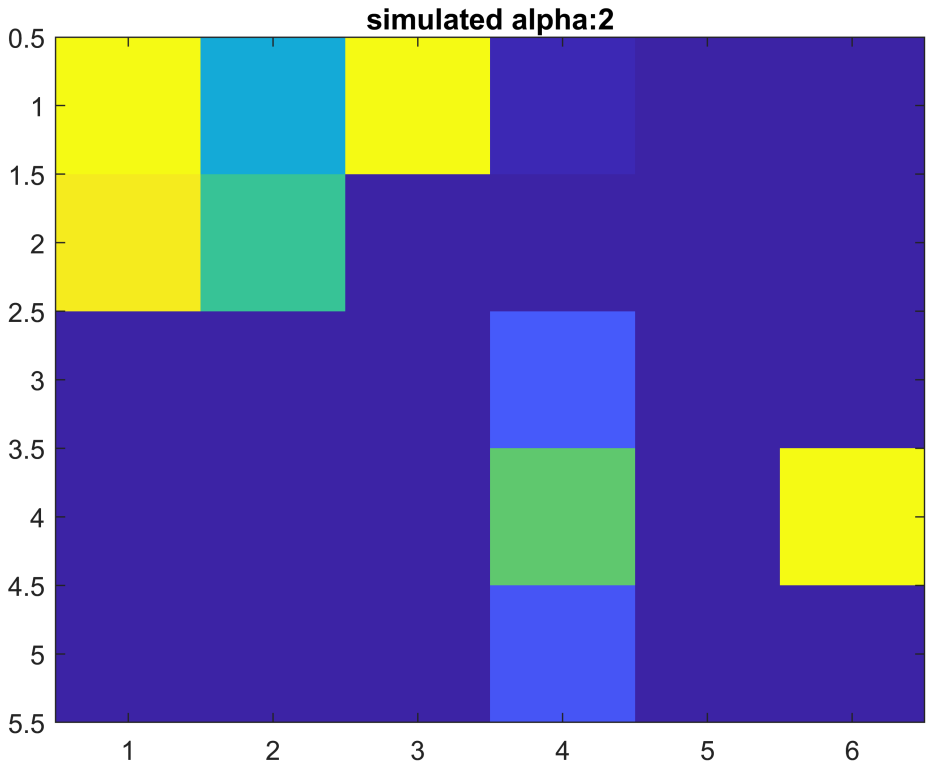


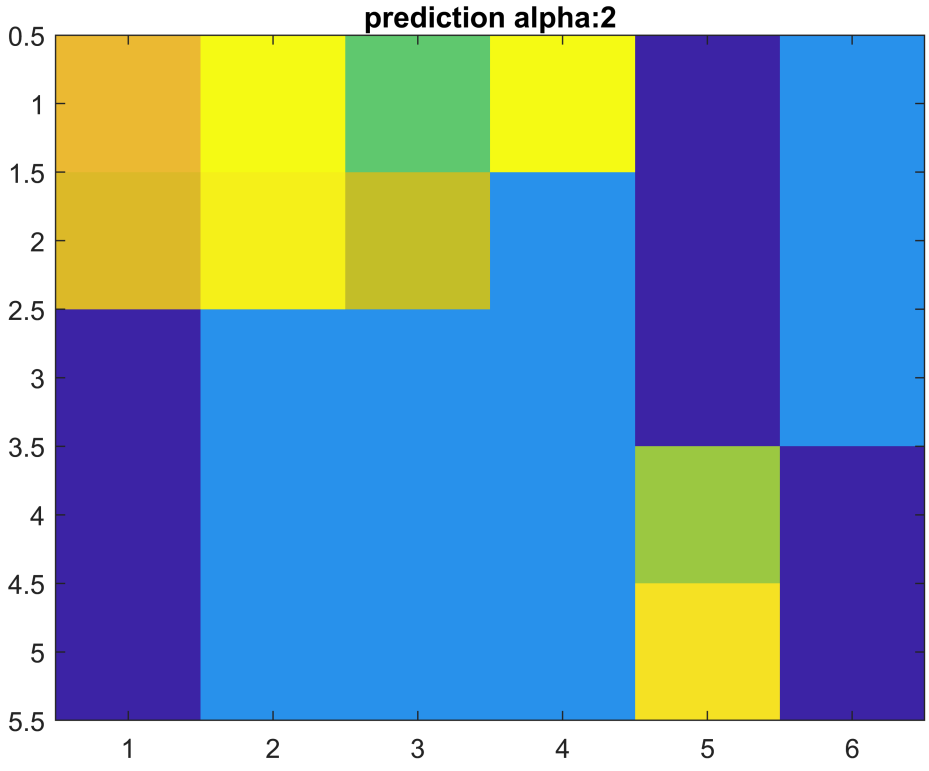

```
c = 0.6290
c = 1.3940
c = 1.1718
c = 1.0509
c = 0.9737
c = 0.6195
c = 0.6202
c = 0.9240
c = 0.8533
c = 0.8091
c = 0.6195
c = 0.6195
c = 0.6196
c = 1.0305
c = 0.9624
c = 0.6195
c = 0.6195
c = 0.6195
c = 0.8238
c = 0.9817
c = 1.4084
c = 1.0629
c = 0.9287
c = 0.8569
c = 0.8121
c = 0.6195
c = 0.6195
c = 0.9237
c = 0.8530
c = 0.8089
c = 0.6195
c = 0.6195
c = 0.6195
c = 1.0304
c = 1.0912
```

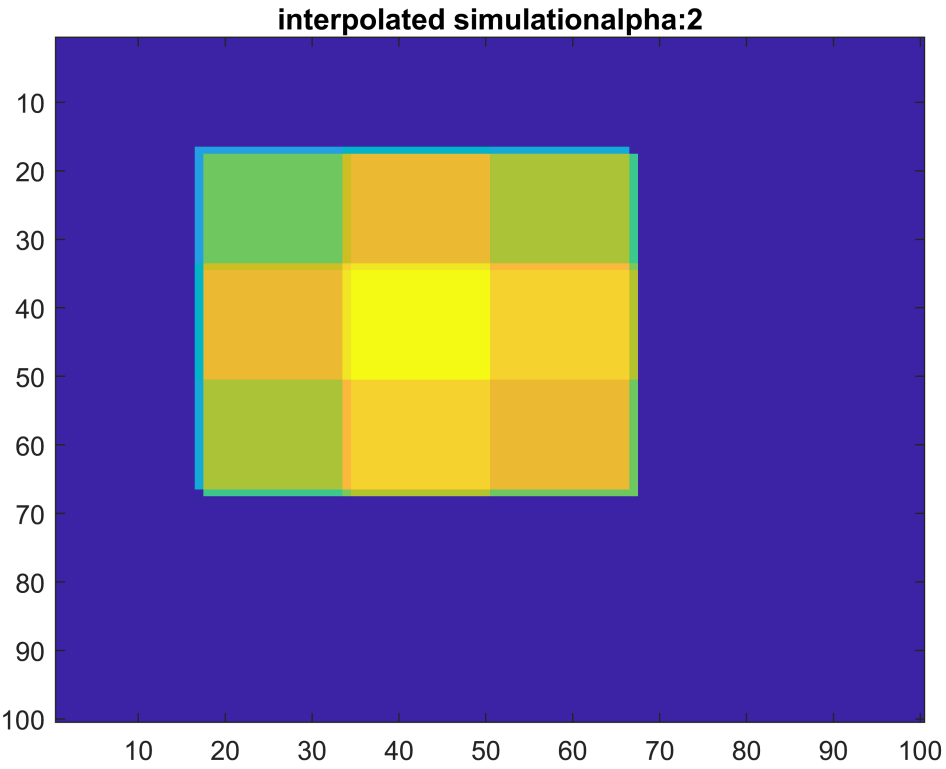
```
c = 0.6195
c = 0.6195
c = 0.6195
c = 0.6285
c = 0.8429
c = 1.4084
c = 1.0629
c = 0.9287
c = 0.8569
c = 0.8121
c = 0.6290
c = 1.6971
c = 1.3871
c = 1.2239
c = 1.1198
c = 0.6195
c = 0.6195
c = 0.6195
c = 1.0304
c = 1.0912
c = 0.6195
c = 0.6195
c = 0.6195
c = 0.6285
c = 0.8429
c = 1.4084
c = 1.0629
c = 0.9287
c = 0.8569
c = 0.8121
c = 0.6290
c = 1.6971
c = 1.3871
c = 1.2239
c = 1.1198
c = 0.6195
c = 0.6195
c = 0.9237
c = 0.8530
c = 0.8089
c = 0.6195
c = 0.6195
c = 0.6195
c = 0.6285
c = 0.8429
c = 1.4084
c = 1.0629
c = 0.9287
c = 0.8569
c = 0.8121
c = 0.6290
c = 1.6971
c = 1.3871
c = 1.2239
c = 1.1198
c = 0.6195
c = 0.6195
c = 0.9237
c = 0.8530
c = 0.8089
c = 0.6195
c = 0.6195
c = 0.6195
c = 1.0304
c = 1.0912
```

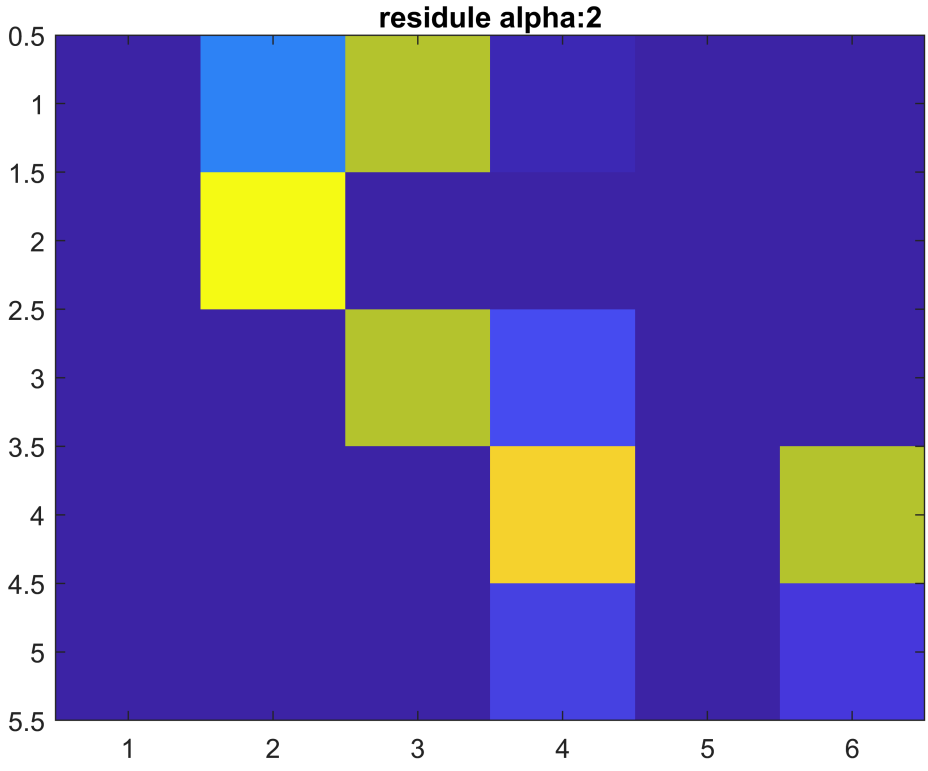
```
alpha = 2
Xhat = 5×6
    1.0095    0.4191    1.0000    0.0218         0    0.0000
    0.9634    0.5809    0.0000    0.0001         0         0
         0    0.0000    0.0000    0.1768         0         0
         0         0    0.0000    0.6349       NaN    1.0000
         0    0.0000    0.0000    0.1664       NaN    0.0000
```




simulated alpha:2
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
5.5
1
2
3
4
5
6

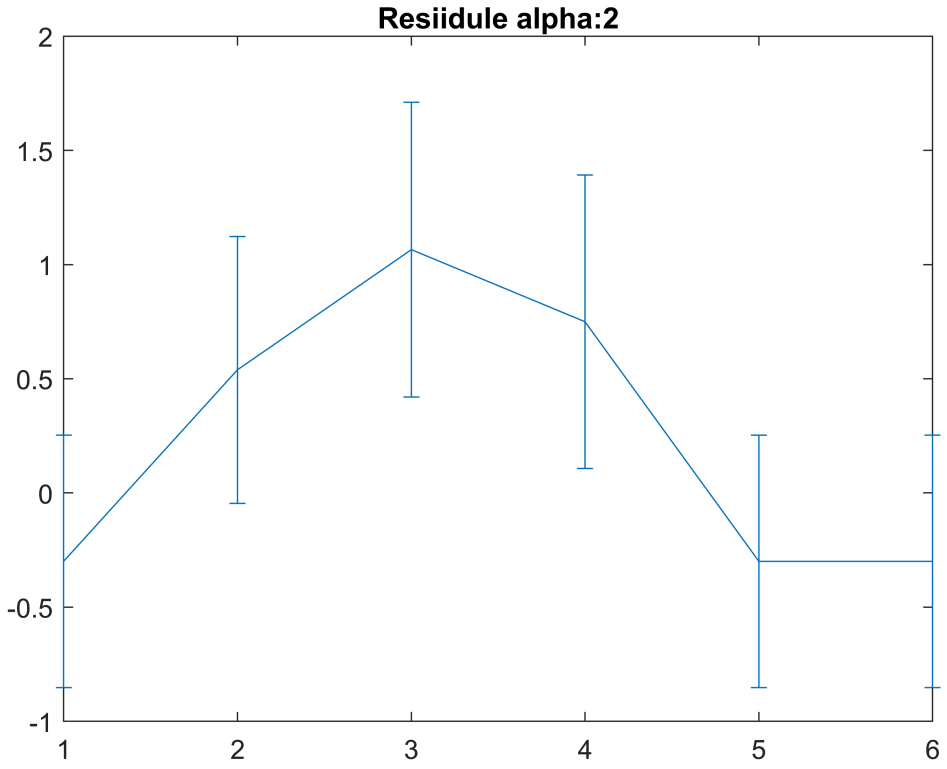

prediction alpha:2
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
5.5
1
2
3
4
5
6



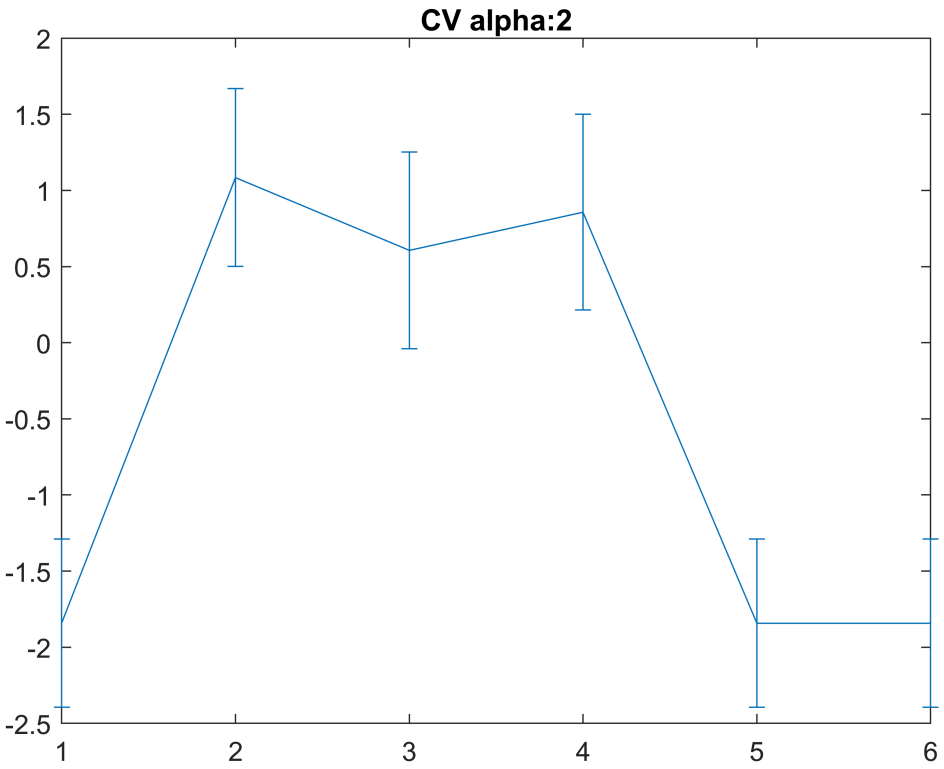



```
%best at alpha = 2
meanRes = zeros(100,6);
stdRes = meanRes;
for steps = 1:100
```

```
    meanRes(steps,:) = mean(mean(Yhat(:,steps,:)-X));
    stdRes(steps,:) = mean(std(Yhat(:,steps,:)-X));
end
CV = stdRes./meanRes;

figure,
errorbar(meanRes(1,:),stdRes(1,:));
title(['Resiidule alpha:',num2str(alpha)])
```




```
figure,
errorbar(CV(1,:),stdRes(1,:));
title(['CV alpha:',num2str(alpha)])
```


CV alpha:2
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
1
2
3
4
5
6