

Matlab code for the results stated in Sections 5.3 and 6.1

Brief description of source codes:

	Sections 5.3	Sections 6.1
Main program	1. Model parameter settings 2. obtain optimal discount matrix	real CMP dataset and its model fitting
Subroutines	1. Discount.m 2. varma32cov.m 3. controller.m	1. getEstimate.m 2. fitting.m 3. getPar1.m 4. disturbance.m 5. controller.m 6. getEstimateSingle.m 7. fitting1.m
Output	Figures 2 and 3	Figures 4

%%% Section 5.3 %%%

%%% model parameter settings %%%

```

qdMEWMA.A=[0;0];
qdMEWMA.B=[0.6,0.3,-0.3;0.6,0.5,0.9];
qdMEWMA.C=[0.181877356326428,0.0834102525982490,-0.0872516073224113;...
0.187271499437739,0.134888131730215,0.257634411550388;];
qdMEWMA.phi=[0.80,-0.20;0.30,0.90];
qdMEWMA.Ahat=[10;10];
qdMEWMA.Bhat=[0.608478241236187,0.297873197696058,-0.296283803320047;...
0.588815187731046,0.468904818125196,0.854900508239482;];
qdMEWMA.Chat=[0.164289125133770,0.0804257633779358,-0.0799966268964126; ...
0.158980100687382,0.126604300893803,0.230823137224660;];
qdMEWMA.phihat=[0.812251902597171,-0.205162972655105; 0.293708754491953, ...
0.880800302648812;];
qdMEWMA.theta=[0.70,0.20;-0.30,0.60];
qdMEWMA.Sigma=eye(2);
qdMEWMA.n=50;
qdMEWMA.opt_kd=0.27;
qdMEWMA.x0=[25;-20;25];
qdMEWMA.tau=[0;0];
load('Sec_5_3_Eta')

```

%%% main program: obtain optimal discount matrix %%%

```

np=size(qdMEWMA.B,1);
[qdMEWMA.omg,qdMEWMA.TMSE]=fminsearchbnd(@(x)
Discount(x,qdMEWMA),[0.5,0.5],zeros(1,np),ones(1,np));

```

%%% fminsearchbnd is obtained on the website of Matlab

%%% <http://www.mathworks.com/matlabcentral/fileexchange/8277-fminsearchbnd-fminsearchcon> %%%

%%% subroutine: Discount.m %%%

```

function [TMSE,non_ranphiom_par,ranphiom_part]=Discount(phiia_omega,qdMEWMA)
omega=diag(phiia_omega);
np=length(omega);
ni=length(qdMEWMA.B');

```

```

gamma0=qdMEWMA.A+qdMEWMA.B*qdMEWMA.x0-qdMEWMA.tau;
M=qdMEWMA.Bhat'/(qdMEWMA.Bhat*qdMEWMA.Bhat');
H=(qdMEWMA.Bhat'/(qdMEWMA.Bhat*qdMEWMA.Bhat'))*qdMEWMA.Bhat;
Q=[eye(np)+qdMEWMA.phi-qdMEWMA.B*M*(qdMEWMA.phihat+omega),-(qdMEWMA.phi-
qdMEWMA.B*M*qdMEWMA.phihat),qdMEWMA.C- qdMEWMA.B*M*qdMEWMA.Chat;...
eye(np),0*eye(np),zeros(np,ni);- M*(qdMEWMA.phihat+omega),M*qdMEWMA.phihat,-
M*qdMEWMA.Chat];

dim=2*np+ni;

sigma_q=reshape(inv(eye(dim^2)- kron(Q',Q'))*reshape([eye(np),zeros(np,dim-
np)];zeros(dim- np,dim)],dim^2,1),dim,dim);
non_ranphiom_part=[gamma0',- qdMEWMA.tau',qdMEWMA.x0']*sigma_q*[gamma0;-
qdMEWMA.tau;qdMEWMA.x0];

Phi1=-(qdMEWMA.B*M*(qdMEWMA.phihat+omega)+qdMEWMA.opt_kd*eye(np)- qdMEWMA.phi-
eye(np));
Phi2=-(qdMEWMA.C*M*(qdMEWMA.phihat+omega)- qdMEWMA.B*M*qdMEWMA.phihat-
qdMEWMA.phi*qdMEWMA.opt_kd*eye(np)- qdMEWMA.opt_kd*eye(np)+qdMEWMA.phi);
Phi3=-(qdMEWMA.phi*qdMEWMA.opt_kd*eye(np)- qdMEWMA.C*M*qdMEWMA.phihat);
Theta1=qdMEWMA.theta-qdMEWMA.opt_kd*eye(np);
Theta2=qdMEWMA.opt_kd*eye(np)*qdMEWMA.theta;

ranphiom_part=sum(diag(reshape(varma32cov(Phi1,Phi2,Phi3,Theta1,Theta2
,qdMEWMA),np,np)));
TMSE=qdMEWMA.n*ranphiom_part+non_ranphiom_part;

%%% subroutine: varma32cov.m %%%

function mat=varma32cov(Phi1,Phi2,Phi3,Theta1,Theta2,qdMEWMA)

sigma=qdMEWMA.Sigma;
nn=length(Phi1);

Inn=[1,0,0,0;0,0,1,0;0,1,0,0;0,0,0,1]; In=eye(nn);
A0=sigma-(Phi1-Theta1)*sigma*(Theta1')-(Phi1*(Phi1-Theta1)+(Phi2-
Theta2))*sigma*(Theta2');
A1=-sigma*(Theta1')-(Phi1-Theta1)*sigma*(Theta2'); A2=-sigma*(Theta2');
a0=reshape(A0,numel(A0),1); a1=reshape(A1,numel(A1),1);
a2=reshape(A2,numel(A2),1);

temp_mat1=eye(nn*nn)-kron(Phi3,Phi3)-
(kron(Phi2,In)+kron(Phi3,Phi1))*Inn*kron(Phi2,In);
temp_mat2=(kron(Phi1,In)+kron(Phi3,Phi2))*Inn+(kron(Phi2,In)+kron(Phi3
,Phi1))*Inn*(kron(Phi1,In)+kron(Phi3,In)*Inn);
temp_mat3=eye(nn*nn)/(eye(nn*nn)-kron(Phi2,In)*Inn-
kron(Phi3,In)*Inn*(kron(Phi1,In)+kron(Phi3,In)*Inn));
temp_mat4=kron(Phi1,In)+kron(Phi3,In)*Inn*kron(Phi2,In);

comb_mat1=temp_mat1-temp_mat2*temp_mat3*temp_mat4;
comb_mat2=temp_mat2*temp_mat3*kron(Phi3,In)*Inn+(kron(Phi2,In)+kron(Ph
i3,Phi1))*Inn;
comb_mat3=temp_mat2*temp_mat3;

mat=(comb_mat1)\(comb_mat2*a2+comb_mat3*a1+a0);

```

```

%%% output of the contour plot in Figure 2%%%

w1=0.01:0.01:1; w2=0.01:0.01:1;
for i=1:100
for j=1:100
com(i,j)= Discount([w1(i),w1(j)],qdMEWMA);
end
end
h=sort(reshape(com,10000,1));
contour(w1,w2,com',h([10,300,700,900,1500,2150,3000,5000,7000,9000]),'showtext',
'on')
axis square;
hold on

plot([0.2,0.2],[0,1],'--g')
plot([0,1],[0.2,0.2],'--g')
plot([qdMEWMA.omg(1),qdMEWMA.omg(1)],[0,1],'-r')
plot([0,1],[qdMEWMA.omg(2),qdMEWMA.omg(2)],'-r')
xlabel('\omega_1')
ylabel('\omega_2')

%%% output for Figure 3%%%
Eta=Sec_5_3_Eta;
[dp.TSSE,dp.yt,dp.xt]=controller(qdMEWMA.omg,qdMEWMA,Eta,'dp',1);
[dp.TSSE1,dp.yt1,dp.xt1]=controller([0.2,0.2],qdMEWMA,Eta,'dp',1);

subplot(2,1,1) plot(dp.yt(1,:),'-rs') hold on plot(dp.yt1(1,:),'-.b')
plot([1,50],[0,0],'--k')
legend(sprintf('%s*=diag(%.2f,%.2f)', '\Omega', qdMEWMA.omg(1), qdMEWMA.o
mg(2)), ...
sprintf('%s_0=diag(%.2f,%.2f)', '\Omega', 0.20, 0.20))
ylabel('y_{1t}') xlabel('Run') hold off subplot(2,1,2)
plot(dp.yt(2,:),'-rs') hold on plot(dp.yt1(2,:),'-.b')
legend(sprintf('%s*=diag(%.2f,%.2f)', '\Omega', qdMEWMA.omg(1), qdMEWMA.o
mg(2)), ...
sprintf('%s_0=diag(%.2f,%.2f)', '\Omega', 0.20, 0.20))
plot([1,50],[0,0],'--k') ylabel('y_{2t}') xlabel('Run')
hold off

%%% Section 6.1 %%%
%%% Real CMP dataset and its model fitting %%%

%%% main function %%%
load('IOmodel')

%%% output for Figure 4 %%%
rand('seed',10^50)
nn=100;
X=random('unif',-1,1,[nn,4]);
dpMEWMA.X= X;

Y1(:,1)=[150;1500];
Eta1=dpMEWMA.Eta1;
for i=2:nn
Y1(:,i)=dpMEWMA.phi*Y1(:,i-1)+dpMEWMA.A+dpMEWMA.B* X(i,:)'+dpMEWMA.C*X(i-
1,:)' +Eta1(:,i-1);

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end
j=1;
par1{j,1}.Yreal1=Y1;
par1{j,1}.X=X;
par1{j,1}.Eta1=Eta1;
nsample=60;
g1{j,1}=getEstimate([par1{j,1}.X(1:
nsample,:),zeros(nsample,1),par1{j,1}.Yreal1(:,1: nsample)'], '2');
Estt1{j,1}=getEstimateSingle([par1{j,1}.X(1:
nsample,:),zeros(nsample,1),par1{j,1}.Yreal1(:,1: nsample)']);
par2{j,1}=getPar1(dpMEWMA,g1{j,1},Estt1{j,1},nsample,[100;2000]);

[dpomg1(j,:),dpTMSE1(j,1)]=fminsearchbnd(@(x)
controller(x,par2{j,1},par1{j,1}.Eta1, 'dp',1),[0.5,0.5],[0,0],ones(1,2),optimse
t('TolX',1e-20));
[somg1(j,:),sTMSE1(j,1)]=fminsearchbnd(@(x)
controller(x,par2{j,1},par1{j,1}.Eta1, 's',1),[0.5,0.5],[0,0],ones(1,2),optimset
('TolX',1e-20));
[STomg1(j,:),STTMSE1(j,1)]=fminsearchbnd(@(x)
controller(x,par2{j,1},par1{j,1}.Eta1, 'ST',1),[0.5,0.8],zeros(1,2),ones(1,2),op
timset('TolX',1e-20));

[dp.TMSE60,dp.Y60]=controller(dpomg1(j,:),par2{j,1},par1{j,1}.Eta1, 'dp',1);
[s.TMSE60,s.Y60]=controller(somg1(j,:),par2{j,1},par1{j,1}.Eta1, 's',1);
[ST.TMSE60,ST.Y60]=controller(STomg1(j,:),par2{j,1},par1{j,1}.Eta1, 'ST',1);

plotControl(dp.Y60,s.Y60,ST.Y60)
subplot(2,1,1)
title('T=60')

%%% subroutine: getEstimate.m %%%

function IOmodel=getEstimate(cmp,method)
speed=cmp(:,1)-mean(cmp(:,1));
press=cmp(:,2)-mean(cmp(:,2));
force=cmp(:,3)-mean(cmp(:,3));
system=cmp(:,4)-mean(cmp(:,4));
time=cmp(:,5)-mean(cmp(:,5));
nonuniformity=cmp(:,6)-mean(cmp(:,6));
removal=cmp(:,7)-mean(cmp(:,7));
data=[speed,press,force,system,time,nonuniformity,removal];
IOmodel.X=[speed,press,force,system];   %%% data input
IOmodel.Y=[nonuniformity,removal];     %%% data output put

np=size(IOmodel.Y,2);
ni=size(IOmodel.X,2);

IOmodel=fitting(IOmodel,method);

IOmodel.Ahat=(eye(np)-IOmodel.phihat)*[mean(cmp(:,6)); ...
mean(cmp(:,7))]- (IOmodel.Bhat+IOmodel.Chat)*[mean(cmp(:,1));...
mean(cmp(:,2));mean(cmp(:,3));mean(cmp(:,4))];

%%% subroutine: fitting.m %%%
function dpMEWMA=fitting(sdpMEWMA,method)
dpMEWMA=sdpMEWMA;

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input=sdpMEWMA.X-repmat(mean(sdpMEWMA.X),length(sdpMEWMA.X),1);
output=sdpMEWMA.Y-repmat(mean(sdpMEWMA.Y),length(sdpMEWMA.Y),1);

np=size(output,2);
ni=size(input,2);
n=length(output);

IOdata=iddata([zeros(1,np);diff(output)],[diff(input(1:n,:));zeros(1,ni)]);

if method=='1'

mfit =ssest(IOdata,4,
'Focus','stability','Form','canonical','Ts',1,'MaxIter',10^3,'Tolerance',10^(-
15));
end

if method=='2'

dy=diff(output);
[ak1]=regress(dy(3:n-1,1),[dy(2:n-2,1), dy(2:n-2,2)]);
[ak2]=regress(dy(3:n-1,2),[dy(2:n-2,1), dy(2:n-2,2)]);
initial=[ak1';ak2'];

A=[0,1,0,0;0,0,0,0;0,0,0,1;0,0,0,0];
B=zeros(4,ni);
C=[1,0,0,0;0,0,1,0];
D=zeros(np,ni);
K=zeros(ni,np);
m=idss(A,B,C,D,K);
m.As=[0,1,0,0;NaN,initial(1,1),NaN,initial(1,2);0,0,0,1;NaN,initial(2,1),NaN,in
itial(2,2)];

m.Bs=zeros(4,ni)*NaN;
m.Cs=[1,0,0,0;0,0,1,0];
m.Ds=zeros(np,ni);
m.Ks=[NaN,NaN;NaN,NaN;NaN,NaN;NaN,NaN];

Opt = ssestOptions;
Opt.Focus='stability';
Opt.SearchOption.Tolerance=10^(-15);
Opt.SearchOption.MaxIter=10^3;
mfit=pem(IOdata,m,Opt);
end

dpMEWMA.phihat=mfit.A([2,4],[2,4]);
dpMEWMA.Bhat=mfit.B([1,3],:);
dpMEWMA.CC=mfit.B([2,4],:);
dpMEWMA.Chat=mfit.B([2,4],:)-dpMEWMA.phihat*dpMEWMA.Bhat;
dpMEWMA.theta_hat=dpMEWMA.phihat-mfit.K([1,3],:);
dpMEWMA.K=mfit.K([1,3],:);
dpMEWMA.aic=aic(mfit);
dpMEWMA.Sigma=mfit.NoiseVariance;

%%% subroutine: getPar.m %%%

function dpMEWMA=getPar1(IOmodel,EST,EST1,n,target)

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dpMEWMA.theta=IOmodel.theta_hat;
dpMEWMA.Sigma=IOmodel.Sigma;
dpMEWMA.A=IOmodel.Ahat;
dpMEWMA.phi=IOmodel.phihat;
dpMEWMA.B=IOmodel.Bhat;
dpMEWMA.C=IOmodel.Chat;

dpMEWMA.n=n;
dpMEWMA.tau=target;

dpMEWMA.Ahat=EST.Ahat;
dpMEWMA.a0=EST.Ahat;
dpMEWMA.phihat=EST.phihat;
dpMEWMA.Bhat=EST.Bhat;
dpMEWMA.Chat=EST.Chat;
dpMEWMA.x0=[NaN;NaN;NaN;NaN];

dpMEWMA.B01=EST1.B01;
dpMEWMA.A01=EST1.A01;
end

%%% subroutine: disturbance.m %%%

function Eta=disturbance(IOmodel,n)
sigma=IOmodel.Sigma;
mu=[0;0];
clear Eta
e=mvnrnd(mu,sigma,n);
e_t1=[0,0,e];
theta=IOmodel.theta;
dEta=e'-theta*e_t1(1:n,:);
Eta(:,1)=dEta(:,1);
for k=2:n
Eta(:,k)=Eta(:,k-1)+dEta(:,k);
end

%%% subroutine: controller.m %%%
Function TSSE,yt,xt]=controller(theta,uqdMEWMA,Etamat,controller,k)
%%% controller={'dp','s','ST'}

ns=50;
A=uqdMEWMA.A;
B=uqdMEWMA.B;
C=uqdMEWMA.C;
phi=uqdMEWMA.phi;
sigma=uqdMEWMA.Sigma;

np=size(B,1);
ni=size(B,2);

tau=uqdMEWMA.tau;
ytau=tau+k*[sqrt(sigma(1,1));sqrt(sigma(2,2))];
x0=uqdMEWMA.B01\'(ytau-uqdMEWMA.A01);
Eta=Etamat;

if controller=='dp'
omg=[theta(1),0;0,theta(2)];

```

```

Bhat=uqdMEWMA.Bhat;
Chat=uqdMEWMA.Chat;
phihat=uqdMEWMA.phihat;
a0=uqdMEWMA.Ahat;
clear yt
yt(:,1)=A+B*x0+Eta(:,1);
at(:,1)=omg*(yt(:,1)-Bhat*x0)+(eye(2,2)-omg)*a0;
xt(:,1)=(eye(ni,ni)-Bhat'*inv(Bhat*Bhat')*Bhat)*x0+
Bhat'*inv(Bhat*Bhat')*(tau- phihat*yt(:,1)-Chat*x0-at(:,1));
yt(:,2)=A+phi*yt(:,1)+B*xt(:,1)+C*x0+Eta(:,2);

at(:,2)=omg*(yt(:,2)-phihat*yt(:,1)-Bhat*xt(:,1)-Chat*x0)+(eye(2,2)-
omg)*at(:,1);
xt(:,2)=(eye(ni,ni)-
Bhat'*inv(Bhat*Bhat')*Bhat)*xt(:,1)+Bhat'*inv(Bhat*Bhat')*(tau-phihat*yt(:,2)-
Chat*xt(:,1)-at(:,2));
yt(:,3)=A+phi*yt(:,2)+B*xt(:,2)+C*xt(:,1)+Eta(:,3);

for i=3:ns-1
at(:,i)=omg*(yt(:,i)-phihat*yt(:,i-1)-Bhat*xt(:,i-1)-Chat*xt(:,i-
2))+ (eye(2,2)-omg)*at(:,i-1);
xt(:,i)=(eye(ni,ni)-Bhat'*inv(Bhat*Bhat')*Bhat)*xt(:,i-
1)+Bhat'*inv(Bhat*Bhat')*(tau-phihat*yt(:,i)-Chat*xt(:,i-1)-at(:,i));
yt(:,i+1)=A+phi*yt(:,i)+B*xt(:,i)+C*xt(:,i-1)+Eta(:,i+1);
end
TSSE=sum(sum((yt(:,1:ns)-repmat(tau,1,ns)).^2));
end

if controller=='s'
omg=[theta(1),0;0,theta(2)];
Bhat=uqdMEWMA.B01;

a0=uqdMEWMA.A01;

tau=uqdMEWMA.tau;

ni=length(uqdMEWMA.B');
clear yt
yt(:,1)=A+B*x0+Eta(:,1);

at(:,1)=omg*(yt(:,1)-Bhat*x0)+(eye(2,2)-omg)*a0;
xt(:,1)=(eye(ni,ni)-
Bhat'*inv(Bhat*Bhat')*Bhat)*x0+Bhat'*inv(Bhat*Bhat')*(tau-at(:,1));
yt(:,2)=A+phi*yt(:,1)+B*xt(:,1)+C*x0+Eta(:,2);

at(:,2)=omg*(yt(:,2)-Bhat*xt(:,1))+(eye(2,2)-omg)*at(:,1);
xt(:,2)=(eye(ni,ni)-
Bhat'*inv(Bhat*Bhat')*Bhat)*xt(:,1)+Bhat'*inv(Bhat*Bhat')*(tau-at(:,2));
yt(:,3)=A+phi*yt(:,2)+B*xt(:,2)+C*xt(:,1)+Eta(:,3);

for i=3:ns-1
at(:,i)=omg*(yt(:,i)-Bhat*xt(:,i-1))+(eye(2,2)-omg)*at(:,i-1);
xt(:,i)=(eye(ni,ni)-Bhat'*inv(Bhat*Bhat')*Bhat)*xt(:,i-
1)+Bhat'*inv(Bhat*Bhat')*(tau-at(:,i));
yt(:,i+1)=A+phi*yt(:,i)+B*xt(:,i)+C*xt(:,i-1)+Eta(:,i+1);
end
TSSE=sum(sum((yt(:,1:ns)-repmat(tau,1,ns)).^2));
end

```

```

if controller=='ST'
    lambda=theta(1);
    rho=theta(2);

    n=50;
    D=uqdMEWMA.phi;

    eta=Etamat;

    A_hat=uqdMEWMA.A01;
    B_hat=uqdMEWMA.B01;
    C_hat=uqdMEWMA.Chat*0;
    D_hat=uqdMEWMA.phihat*0;

    NumOutput=size(B,1);
    NumInput=size(B,2);

    yt=zeros(NumOutput,n+1)*NaN;
    xt=zeros(NumInput,n+1);
    At=zeros(NumOutput,n+1);

    i=1;
    At(:,i)=A_hat;
    xt(:,i)=x0;
    ut=zeros(n+1,NumOutput+2*NumInput);
    parat=[D_hat,B_hat,C_hat]; % dim: NumOutput x (NumOutput+2*NumInput)
    P0=rho*eye(NumOutput+2*NumInput);
    Pt=zeros(n+1,NumOutput,NumOutput+2*NumInput,NumOutput+2*NumInput);
    Kt=zeros(NumOutput+2*NumInput,NumOutput);
    et=zeros(1,NumOutput);

    i=i+1;
    temp_parat=parat;
    yt(:,i)=A+B*xt(:,i-1)+eta(:,i-1);
    ut(i,:)=[zeros(NumOutput,1)',(xt(:,i-1))',zeros(NumInput,1)'];
    for iii=1:NumOutput
        Kt(:,iii)=P0*(ut(i,:)')/(lambda+ut(i,:)*P0*(ut(i,:)'));
        et(1,iii)=yt(iii,i)-ut(i,:)*(temp_parat(iii,:));
        parat(iii,:)=temp_parat(iii,:)+(Kt(:,iii)')*et(1,iii);
        Pt(i,iii,:,:)=reshape((eye(NumOutput+2*NumInput)-
Kt(:,iii)*ut(i,:))*P0+(Kt(:,iii)')*P0*(ut(i,:)')/(NumOutput+2*NumInput))*eye(N
umOutput+2*NumInput),1,1,NumOutput+2*NumInput,NumOutput+2*NumInput);
    end

    XXX=(parat(:,(NumOutput+1):(NumOutput+NumInput))')*parat(:,(NumOutput+1):(NumOu
tput+NumInput));
    invXXX=pinv(XXX);
    xt(:,i)=xt(:,i-
1)+invXXX*(parat(:,(NumOutput+1):(NumOutput+NumInput))')*(tau-yt(:,i)-
parat(:,1:NumOutput))*(yt(:,i))-
parat(:,(NumOutput+NumInput+1):(NumOutput+2*NumInput))*(xt(:,i-1)));

    i=i+1;
    temp_parat=parat;
    yt(:,i)=D*yt(:,i-1)+A+B*xt(:,i-1)+C*xt(:,i-2)+eta(:,i);
    ut(i,:)=[yt(:,i-1)',xt(:,i-1)','-xt(:,i-2)',xt(:,i-2)'];
    for iii=1:NumOutput

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        Kt(:,iii)=reshape(Pt(i-
1,iii,:,:),NumOutput+2*NumInput,NumOutput+2*NumInput)*(ut(i,:)))/(lambda+ut(i,:
))*reshape(Pt(i-
1,iii,:,:),NumOutput+2*NumInput,NumOutput+2*NumInput)*(ut(i,:));
        et(1,iii)=yt(iii,i)-yt(iii,i-1)-ut(i,:)*(temp_parat(iii,:));
        parat(iii,:)=temp_parat(iii,:)+(Kt(:,iii))*et(1,iii);
        Pt(i,iii,:)=reshape((eye(NumOutput+2*NumInput)-
Kt(:,iii))*ut(i,:))*reshape(Pt(i-
1,iii,:,:),NumOutput+2*NumInput,NumOutput+2*NumInput)+(Kt(:,iii))*reshape(Pt(i-
1,iii,:,:),NumOutput+2*NumInput,NumOutput+2*NumInput)*(ut(i,:))/(NumOutput+2*N
umInput))*eye(NumOutput+2*NumInput),1,1,NumOutput+2*NumInput,NumOutput+2*NumInp
ut);
    end

XXX=(parat(:,(NumOutput+1):(NumOutput+NumInput)))*parat(:,(NumOutput+1):(NumOu
tput+NumInput)));
    invXXX=pinv(XXX);
    xt(:,i)=xt(:,i-
1)+invXXX*(parat(:,(NumOutput+1):(NumOutput+NumInput)))*(tau-yt(:,i)-
parat(:,1:NumOutput))*(yt(:,i)-yt(:,i-1))-
parat(:,(NumOutput+NumInput+1):(NumOutput+2*NumInput))*(xt(:,i-1)-xt(:,i-2)));

    while(i<=n)
        i=i+1;
        temp_parat=parat;
        yt(:,i)=D*yt(:,i-1)+A+B*xt(:,i-1)+C*xt(:,i-2)+eta(:,i);
        ut(i,:)=[yt(:,i-1)'-yt(:,i-2)',xt(:,i-1)'-xt(:,i-2)',xt(:,i-2)'-xt(:,i-
3)'];
        for iii=1:NumOutput
            Kt(:,iii)=reshape(Pt(i-
1,iii,:,:),NumOutput+2*NumInput,NumOutput+2*NumInput)*(ut(i,:))/(lambda+ut(i,:
))*reshape(Pt(i-
1,iii,:,:),NumOutput+2*NumInput,NumOutput+2*NumInput)*(ut(i,:));
            et(1,iii)=yt(iii,i)-yt(iii,i-1)-ut(i,:)*(temp_parat(iii,:));
            parat(iii,:)=temp_parat(iii,:)+(Kt(:,iii))*et(1,iii);
            Pt(i,iii,:)=reshape((eye(NumOutput+2*NumInput)-
Kt(:,iii))*ut(i,:))*reshape(Pt(i-
1,iii,:,:),NumOutput+2*NumInput,NumOutput+2*NumInput)+(Kt(:,iii))*reshape(Pt(i-
1,iii,:,:),NumOutput+2*NumInput,NumOutput+2*NumInput)*(ut(i,:))/(NumOutput+2*N
umInput))*eye(NumOutput+2*NumInput),1,1,NumOutput+2*NumInput,NumOutput+2*NumInp
ut);
        end

XXX=(parat(:,(NumOutput+1):(NumOutput+NumInput)))*parat(:,(NumOutput+1):(NumOu
tput+NumInput)));
    invXXX=pinv(XXX);
    xt(:,i)=xt(:,i-
1)+invXXX*(parat(:,(NumOutput+1):(NumOutput+NumInput)))*(tau-yt(:,i)-
parat(:,1:NumOutput))*(yt(:,i)-yt(:,i-1))-
parat(:,(NumOutput+NumInput+1):(NumOutput+2*NumInput))*(xt(:,i-1)-xt(:,i-2)));
    end
    TSSE=sum(sum((yt(:,2:n+1)-repmat(tau,1,n)).^2));
end

%%% subroutine: getEstimateSingle.m %%%

```

```

function IOmodel=getEstimateSingle(cmp)
speed=cmp(:,1)-mean(cmp(:,1));
press=cmp(:,2)-mean(cmp(:,2));
force=cmp(:,3)-mean(cmp(:,3));
system=cmp(:,4)-mean(cmp(:,4));
time=cmp(:,5)-mean(cmp(:,5));
nonuniformity=cmp(:,6)-mean(cmp(:,6));
removal=cmp(:,7)-mean(cmp(:,7));
data=[speed,press,force,system,time,nonuniformity,removal];
IOmodel.X=[speed,press,force,system];   %% data input
IOmodel.Y=[nonuniformity,removal];      %% data output put

np=size(IOmodel.Y,2);
ni=size(IOmodel.X,2);

IOmodel=fitting1(IOmodel);
IOmodel.A01=eye(np)*[mean(cmp(:,6));mean(cmp(:,7))]-...

(IOmodel.B01)*[mean(cmp(:,1));mean(cmp(:,2));mean(cmp(:,3));mean(cmp(:,4))];

%%% subroutine: getEstimateSingle.m %%%
function dpMEWMA=fitting1(sdpMEWMA)
dpMEWMA=sdpMEWMA;

input=sdpMEWMA.X-repmat(mean(sdpMEWMA.X),length(sdpMEWMA.X),1);
output=sdpMEWMA.Y-repmat(mean(sdpMEWMA.Y),length(sdpMEWMA.Y),1);

np=size(output,2);
ni=size(input,2);
n=length(output);

Opt = ssestOptions;
Opt.Focus = 'stability';

IOdata=iddata([zeros(1,np);diff(output)],[diff(input(1:n,:));zeros(1,ni)]);
sss =ssest(IOdata,2, Opt, 'Form', 'canonical', 'Ts',1);

dpMEWMA.B01=sss.Structure.b.Value;

```