Matlab Code for the Case Study in Chapter 8

ANFIS code:

```
clear;
global a;
h=1;
sum=0;
ya=zeros(4,5);
y=zeros(1,4);
yb=zeros(4,25);
sumc=0;
yac=zeros(4,5);
yc=zeros(1,4);
ybc=zeros(4,25);
r=zeros(1,300);
a=zeros(225,19);
% Seting the first value of variables

da1=0;
da2=0;
da3=0;
da4=0;
da5=0;
da6=0;
da7=0;
da8=0;
da9=0;
da10=0;

db1=0;
db2=0;
db3=0;
db4=0;
db5=0;
db6=0;
db7=0;
db8=0;
db9=0;
db10=0;


dc1=0;
dc2=0;
dc3=0;
dc4=0;
dc5=0;
dc6=0;
dc7=0;
dc8=0;
dc9=0;
dc10=0;

%xre=def(1);
dw=[0 0 0 0 0 0 0 0 0];
w=[0 0 0 0 0 0 0 0 0];
% bell shape initial input
c1=2.6;
b1=0.5;
a1=0.08;
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c2=3.35;
b2=0.5;
a2=0.08;
c3=3.75;
b3=0.5;
a3=0.08;
c4=4.15;
b4=0.5;
a4=0.08;
c5=4.7;
b5=0.5;
a5=0.08;
c6=1.25;
b6=0.5;
a6=0.08;
c7=1.4;
b7=0.5;
a7=0.08;
c8=1.8;
b8=0.5;
a8=0.08;
c9=2.15;
b9=0.5;
a9=0.08;
c10=2.45;
b10=0.5;
a10=0.08;


%training data
tdata=[0 0 0 0 0 0 0 0 0 0;1.95 4 0 0 0 0 0 0 0 0;1.4 2.5 0 0 0 0 0 0 0 0;2.5 5 0 0 0 0 0 0 0 0];
cdata=[0 0 0 0 0 0 0 0 0 0;0 0 0 0 0 0 0 0 0 0;0 0 0 0 0 0 0 0 0 0;0 0 0 0 0 0 0 0 0 0];
%checking data
% Loop for starting training
for k=1:4
% x1 , x2 input
x1=tdata(k,1);
x2=tdata(k,2);

xc1=cdata(k,1);
xc2=cdata(k,2);
%yd = desire output
yd=[0.3 0.5 0.7 0.2];
ydc=[0 0 0 0];
e=0;
% finding the membership function of x1 , x2 based on the triangular
% function (ai , bi are changing during learning algorithm)
if (x1>=2.5) && (x1<3.1)
    ya(k,1)=1;
    yac(k,1)=1;
end
if (x1>=3.1) && (x1<3.2)
    ya(k,1)=1/(1+(((x1-c1)/a1).^(2*b1)));
    yac(k,1)=1/(1+(((x1-c1)/a1).^(2*b1)));
    ya(k,2)=1/(1+(((x1-c2)/a2).^(2*b2)));
    yac(k,2)=1/(1+(((x1-c2)/a2).^(2*b2)));
end
if (x1>=3.2) && (x1<3.5)
    ya(k,2)=1/(1+(((x1-c2)/a2).^(2*b2)));
    yac(k,2)=1/(1+(((x1-c2)/a2).^(2*b2)));
end
if (x1>=3.5) && (x1<3.6)
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    ya(k,2)=1/(1+(((x1-c2)/a2).^(2*b2)));
    yac(k,2)=1/(1+(((x1-c2)/a2).^(2*b2)));
    ya(k,3)=1/(1+(((x1-c3)/a3).^(2*b3)));
    yac(k,3)=1/(1+(((x1-c3)/a3).^(2*b3)));
end
if (x1>=3.6) && (x1<3.9)
    ya(k,3)=1/(1+(((x1-c3)/a3).^(2*b3)));
    yac(k,3)=1/(1+(((x1-c3)/a3).^(2*b3)));
end
if (x1>=3.9) && (x1<4)
    ya(k,3)=1/(1+(((x1-c3)/a3).^(2*b3)));
    yac(k,3)=1/(1+(((x1-c3)/a3).^(2*b3)));
    ya(k,4)=1/(1+(((x1-c4)/a4).^(2*b4)));
    yac(k,4)=1/(1+(((x1-c4)/a4).^(2*b4)));
end
if (x1>=4) && (x1<4.3)
    ya(k,4)=1/(1+(((x1-c4)/a4).^(2*b4)));
    yac(k,4)=1/(1+(((x1-c4)/a4).^(2*b4)));
end
if (x1>=4.3) && (x1<4.4)
    ya(k,4)=1/(1+(((x1-c4)/a4).^(2*b4)));
    yac(k,4)=1/(1+(((x1-c4)/a4).^(2*b4)));
    ya(k,5)=1/(1+(((x1-c5)/a5).^(2*b5)));
    yac(k,5)=1/(1+(((x1-c5)/a5).^(2*b5)));
end
if (x1>=4.4) && (x1<5)
    ya(k,5)=1;
    yac(k,5)=1;
end

%************************************
if (x2>=1) && (x2<1.25)
    yb(k,1)=1;
    ybc(k,1)=1;
end
if (x2>=1.25) && (x2<1.35)
    yb(k,1)=1/(1+(((x1-c6)/a6).^(2*b6)));
    ybc(k,1)=1/(1+(((x1-c6)/a6).^(2*b6)));
    yb(k,2)=1/(1+(((x1-c7)/a7).^(2*b7)));
    ybc(k,2)=1/(1+(((x1-c7)/a7).^(2*b7)));
end
if (x2>=1.35) && (x2<1.5)
    yb(k,2)=1/(1+(((x2-c7)/a7).^(2*b7)));
    ybc(k,2)=1/(1+(((x2-c7)/a7).^(2*b7)));
end
if (x2>=1.5) && (x2<1.6)
    yb(k,2)=1/(1+(((x2-c7)/a7).^(2*b7)));
    ybc(k,2)=1/(1+(((x2-c7)/a7).^(2*b7)));
    yb(k,3)=1/(1+(((x2-c8)/a8).^(2*b8)));
    ybc(k,3)=1/(1+(((x2-c8)/a8).^(2*b8)));
end
if (x2>=1.6) && (x2<1.9)
    yb(k,3)=1/(1+(((x2-c8)/a8).^(2*b8)));
    ybc(k,3)=1/(1+(((x2-c8)/a8).^(2*b8)));
end
if (x2>=1.9) && (x2<2)
    yb(k,3)=1/(1+(((x2-c8)/a8).^(2*b8)));
    ybc(k,3)=1/(1+(((x2-c8)/a8).^(2*b8)));
    yb(k,4)=1/(1+(((x2-c9)/a9).^(2*b9)));
    ybc(k,4)=1/(1+(((x2-c9)/a9).^(2*b9)));
end
if (x2>=2) && (x2<2.3)
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    yb(k,4)=1/(1+(((x2-c9)/a9).^(2*b9)));
    ybc(k,4)=1/(1+(((x2-c9)/a9).^(2*b9)));
end
if (x2>=2.3) && (x2<2.4)
    yb(k,4)=1/(1+(((x2-c9)/a9).^(2*b9)));
    ybc(k,4)=1/(1+(((x2-c9)/a9).^(2*b9)));
    yb(k,5)=1/(1+(((x2-c10)/a10).^(2*b10)));
    ybc(k,5)=1/(1+(((x2-c10)/a10).^(2*b10)));
end
if (x2>=2.4) && (x2<2.65)
    yb(k,5)=1;
    ybc(k,5)=1;
end

% rules: definging the rules for each variables for example w1= ya1(good)*yb1(good)
l=1;
for i=1:5
   for j=1:5
w(l)=ya(k,i)*yb(k,j);
wc(l)=yac(k,i)*ybc(k,j);
l=l+1;
   end
end

% the function for each rule(first order sugeno)
for i= 1:25
tw(k,i)=w(i);
twc(k,i)=wc(i);
end;
end;

% the function for each rule(zero-order sugeno)
f(1)= 0.7;
f(2)= 0.6;
f(3)= 0.9;
f(4)= 0.9;
f(5)= 0.8;
f(6)= 0.75;
f(7)= 0.8;
f(8)= 0.6;
f(9)= 0.8;
f(10)= 0.7;
f(11)= 0.6;
f(12)= 0.9;
f(13)= 0.9;
f(14)= 0.8;
f(15)= 0.75;
f(16)= 0.8;
f(17)= 0.6;
f(18)= 0.8;
f(19)= 0.7;
f(20)= 0.6;
f(21)= 0.9;
f(22)= 0.9;
f(23)= 0.8;
f(24)= 0.75;
f(25)= 0.8;

% first of epoch for learning algorithm
w1=w;
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```
% the number of epoch
maxcycle=300;
% the learning rate
alpha=.02;
%the acceptance erorr
ssegoal=.005;
for m=1:maxcycle
   for i= 1:4
      sum(i)=0;
      sumc(i)=0;
      for j= 1:25
   sum(i)=tw(i,j)+sum(i)+1;
   sumc(i)=twc(i,j)+sumc(i);
      end;
   end;
for j=1:4
   y(j)=0;
   yc(j)=0;
for i=1:25
   wn(j,i)= (tw(j,i))/sum(j);
   wy(j,i)=f(j)*wn(j,i);
   y(j)=y(j)+wy(j,i);
   wnc(j,i)= (twc(j,i))/sumc(j);
   wyc(j,i)=f(j)*wnc(j,i);
   yc(j)=yc(j)+wyc(j,i);
end
end
   for j=1:4
      e(j)=yd(j)-y(j);
      ec(j)=ydc(j)-yc(j);
   end
rmse=sqrt(abs(e(1)+e(2)+e(3)+e(4))/4);
rmsec=sqrt(abs(ec(1)+ec(2)+ec(3)+ec(4))/4);
re(m)=rmse;
rec(m)=rmsec;
if rmse<ssegoal;break;end;
for j=1:4;
for t=1:25;
if (tw(j,t)~=0)
%defining the changes of w
   dw(j,t)=(alpha*e(j)*f(t)*wn(j,t)*(1-wn(j,t))*(1/tw(j,t)));
   tw(j,t)=tw(j,t)+dw(j,t);
   dwc(j,t)=(alpha*ec(j)*f(t)*wnc(j,t)*(1-wnc(j,t))*(1/twc(j,t)));
   twc(j,t)=twc(j,t)+dwc(j,t);
end;
end;
end;
end;

%changing the da & db
for j=1:4;
da1=(tw(j,1)+tw(j,2)+tw(j,3)+tw(j,4)+tw(j,5))*(2*b1*ya(j,1)*ya(j,1))*((x1-
c1)^(2*b1))/(a1^(2*b1+1))*yb(j,1);
db1=(tw(j,1)+tw(j,2)+tw(j,3)+tw(j,4)+tw(j,5))*(exp(x1-c1)*2*a1^(2*b1)/(a1^(2*b1)+(x1-
c1)^(2*b1)))*yb(j,1);
dc1=(tw(j,1)+tw(j,2)+tw(j,3)+tw(j,4)+tw(j,5))*(ya(j,1)*ya(j,1)*2*b1*((x1-c1)/a1)^(2*b1-1))*yb(j,1);

da2=(tw(j,6)+tw(j,7)+tw(j,8)+tw(j,9)+tw(j,10))*((2*b2*ya(j,2)*ya(j,2)*(x1-
c2)^(2*b2))/a1^(2*b2+1))*yb(j,2);
db2=(tw(j,6)+tw(j,7)+tw(j,8)+tw(j,9)+tw(j,10))*(exp(x1-c2)*2*a2^(2*b2)/(a2.^(2*b2)+(x1-
c2)^(2*b2)))*yb(j,2);
dc2=(tw(j,6)+tw(j,7)+tw(j,8)+tw(j,9)+tw(j,10))*(ya(j,2)*ya(j,2)*2*b2*((x1-c2)/a2)^(2*b2-1))*yb(j,2);
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da3=(tw(j,11)+tw(j,12)+tw(j,13)+tw(j,14)+tw(j,15))*((2*b3*ya(j,3)*ya(j,3)*(x1-
c3)^(2*b3))/a3^(2*b3+1))*yb(j,3);
db3=(tw(j,11)+tw(j,12)+tw(j,13)+tw(j,14)+tw(j,15))*(exp(x1-c3)*2*a3^(2*b3)/(a3^(2*b3)+(x1-
c3)^(2*b3)))*yb(j,3);
dc3=(tw(j,11)+tw(j,12)+tw(j,13)+tw(j,14)+tw(j,15))*(ya(j,3)*ya(j,3)*2*b3*((x1-c3)/a3)^(2*b3-
1))*yb(j,3);

da4=(tw(j,16)+tw(j,17)+tw(j,18)+tw(j,19)+tw(j,20))*((2*b4*ya(j,4)*ya(j,4)*(x1-
c4)^(2*b4))/a4^(2*b4+1))*yb(j,4);
db4=(tw(j,16)+tw(j,17)+tw(j,18)+tw(j,19)+tw(j,20))*(exp(x1-c4)*2*a4^(2*b4)/(a4^(2*b4)+(x1-
c4)^(2*b4)))*yb(j,4);
dc4=(tw(j,16)+tw(j,17)+tw(j,18)+tw(j,19)+tw(j,20))*(ya(j,4)*ya(j,4)*2*b4*((x1-c4)/a4)^(2*b4-
1))*yb(j,4);

da5=(tw(j,21)+tw(j,22)+tw(j,23)+tw(j,24)+tw(j,25))*((2*b5*ya(j,5)*yb(j,5)*(x1-
c5)^(2*b5))/a5^(2*b5+1))*yb(j,5);
db5=(tw(j,21)+tw(j,22)+tw(j,23)+tw(j,24)+tw(j,25))*(exp(x1-c5)*2*a5^(2*b5)/(a5^(2*b5)+(x1-
c5)^(2*b5)))*yb(j,5);
dc5=(tw(j,21)+tw(j,22)+tw(j,23)+tw(j,24)+tw(j,25))*(yb(j,5)*yb(j,5)*2*b5*((x1-c5)/a5)^(2*b5-
1))*yb(j,5);
%**********
da6=(tw(j,1)+tw(j,2)+tw(j,3)+tw(j,4)+tw(j,5))*(2*b6*yb(j,1)*yb(j,1))*((x2-
c6)^(2*b6))/(a6^(2*b6+1))*ya(j,1);
db6=(tw(j,1)+tw(j,2)+tw(j,3)+tw(j,4)+tw(j,5))*(exp(x2-c6)*2*a6^(2*b6)/(a6^(2*b6)+(x2-
c6)^(2*b6)))*ya(j,1);
dc6=(tw(j,1)+tw(j,2)+tw(j,3)+tw(j,4)+tw(j,5))*(yb(j,1)*yb(j,1)*2*b6*((x2-c6)/a6)^(2*b6-1))*ya(j,1);

da7=(tw(j,6)+tw(j,7)+tw(j,8)+tw(j,9)+tw(j,10))*((2*b7*yb(j,2)*yb(j,2)*(x2-
c7)^(2*b7))/a7^(2*b7+1))*ya(j,2);
db7=(tw(j,6)+tw(j,7)+tw(j,8)+tw(j,9)+tw(j,10))*(exp(x2-c7)*2*a7^(2*b7)/(a7.^(2*b7)+(x2-
c7)^(2*b7)))*ya(j,2);
dc7=(tw(j,6)+tw(j,7)+tw(j,8)+tw(j,9)+tw(j,10))*(yb(j,2)*yb(j,2)*2*b7*((x2-c7)/a7)^(2*b7-1))*ya(j,2);

da8=(tw(j,11)+tw(j,12)+tw(j,13)+tw(j,14)+tw(j,15))*((2*b8*yb(j,3)*yb(j,3)*(x2-
c8)^(2*b8))/a8^(2*b8+1))*ya(j,3);
db8=(tw(j,11)+tw(j,12)+tw(j,13)+tw(j,14)+tw(j,15))*(exp(x2-c8)*2*a8^(2*b8)/(a8^(2*b8)+(x2-
c8)^(2*b8)))*ya(j,3);
dc8=(tw(j,11)+tw(j,12)+tw(j,13)+tw(j,14)+tw(j,15))*(yb(j,3)*yb(j,3)*2*b8*((x2-c8)/a8)^(2*b8-
1))*ya(j,3);

da9=(tw(j,16)+tw(j,17)+tw(j,18)+tw(j,19)+tw(j,20))*((2*b9*yb(j,4)*yb(j,4)*(x2-
c9)^(2*b9))/a9^(2*b9+1))*ya(j,4);
db9=(tw(j,16)+tw(j,17)+tw(j,18)+tw(j,19)+tw(j,20))*(exp(x2-c9)*2*a9^(2*b9)/(a4^(2*b9)+(x2-
c9)^(2*b9)))*ya(j,4);
dc9=(tw(j,16)+tw(j,17)+tw(j,18)+tw(j,19)+tw(j,20))*(yb(j,4)*yb(j,4)*2*b9*((x2-c9)/a9)^(2*b9-
1))*ya(j,4);

da10=(tw(j,21)+tw(j,22)+tw(j,23)+tw(j,24)+tw(j,25))*((2*b10*yb(j,5)*yb(j,5)*(x2-
c10)^(2*b10))/a10^(2*b10+1))*ya(j,5);
db10=(tw(j,21)+tw(j,22)+tw(j,23)+tw(j,24)+tw(j,25))*(exp(x2-c10)*2*a10^(2*b10)/(a10^(2*b10)+(x2-
c10)^(2*b10)))*ya(j,5);
dc10=(tw(j,21)+tw(j,22)+tw(j,23)+tw(j,24)+tw(j,25))*(yb(j,5)*yb(j,5)*2*b10*((x2-c10)/a10)^(2*b10-
1))*ya(j,5);



a1=a1+da1;
a2=a2+da2;
a3=a3+da3;
a4=a4+da4;
a5=a5+da5;
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a6=a6+da6;
a7=a7+da7;
a8=a8+da8;
a9=a9+da9;
a10=a10+da10;

b1=b1+db1;
b2=b2+db2;
b3=b3+db3;
b4=b4+db4;
b5=b5+db5;
b6=b6+db6;
b7=b7+db7;
b8=b8+db8;
b9=b9+db9;
b10=b10+db10;

c1=c1+dc1;
c2=c2+dc2;
c3=c3+dc3;
c4=c4+dc4;
c5=c5+dc5;
c6=c6+dc6;
c7=c7+dc7;
c8=c8+dc8;
c9=c9+dc9;
c10=c10+dc10;

end;
%drawing the new figure based on the learning data and change ai and bi
x1=[2.5:0.04:5];
x2=[1:0.025:2.5];

yaa1=zeros(length(x1));
yaa2=zeros(length(x1));
yaa3=zeros(length(x1));
yaa4=zeros(length(x1));
yaa5=zeros(length(x1));

ya1=zeros(length(x1));
ya2=zeros(length(x1));
ya3=zeros(length(x1));
ya4=zeros(length(x1));
ya5=zeros(length(x1));

ybb1=zeros(length(x2));
ybb2=zeros(length(x2));
ybb3=zeros(length(x2));
ybb4=zeros(length(x2));
ybb5=zeros(length(x2));

yb1=zeros(length(x2));
yb2=zeros(length(x2));
yb3=zeros(length(x2));
yb4=zeros(length(x2));
yb5=zeros(length(x2));

cc1=2.5;
bb1=0.5;
aa1=0.08;
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cc2=3.25;
bb2=0.5;
aa2=0.08;

cc3=3.75;
bb3=0.5;
aa3=0.08;

cc4=4.15;
bb4=0.5;
aa4=0.08;

cc5=5;
bb5=0.5;
aa5=0.08;


cc6=1.25;
bb6=0.5;
aa6=0.08;

cc7=1.4;
bb7=0.5;
aa7=0.08;

cc8=1.75;
bb8=0.5;
aa8=0.08;

cc9=2.15;
bb9=0.5;
aa9=0.08;

cc10=2.35;
bb10=0.5;
aa10=0.08;

for i=1:60
% drawing the changed figure
if (x1(i)>=c1-2*b1) && (x1(i)<=c1+2*b1)
    yaa1(i)=max(min(abs(1/(1+(((x1(i)-c1)/a1)^(2*b1)))),1),0);
end
% drawing initial figure
if (x1(i)>=2.5) && (x1(i)<3.2)
    ya1(i)=max(min(1/(1+(((x1(i)-cc1)/aa1)^(2*bb1))),1),0);
end
if (x1(i)>=2.5) && (x1(i)<=3)
   ya1(i)=1;
   yaa1(i)=1;
end
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
if (x1(i)>=3.1) && (x1(i)<=3.6)
    ya2(i)=max(min(abs(1/(1+(((x1(i)-cc2)/aa2)^(2*bb2)))),1),0);
end
if (x1(i)>=c2-2*b2) && (x1(i)<=c2+2*b2)
    yaa2(i)=max(min(abs(1/(1+(((x1(i)-c2)/a2)^(2*b2)))),1),0);
end
if (x1(i)>=c3-2*b3) && (x1(i)<=c3+2*b3)
    yaa3(i)=max(1/(1+(((x1(i)-cc3)/aa3)^(2*bb3)))),1/(1+(((x1(i)-cc2)/aa2)^(2*bb2)));
end
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%******************
if (x1(i)>=3.5) && (x1(i)<=4)
   ya3(i)=max(min(abs(1/(1+(((x1(i)-cc3)/aa3)^(2*bb3)))),1),0);
end
if (x1(i)>=c3-2*b3) && (x1(i)<=c3+2*b3)
   yaa3(i)=max(min(abs(1/(1+(((x1(i)-c3)/a3)^(2*b3)))),1),0);
end
if (x1(i)>=c4-2*b4) && (x1(i)<=c4+2*b4)
   yaa4(i)=max(1/(1+(((x1(i)-cc4)/aa4)^(2*bb4)))),1/(1+(((x1(i)-cc3)/aa3)^(2*bb3)));
end
%*********************
if (x1(i)>=3.9) && (x1(i)<=4.4)
   ya4(i)=max(min(abs(1/(1+(((x1(i)-cc4)/aa4)^(2*bb4)))),1),0);
end
if (x1(i)>=c4-2*b4) && (x1(i)<=c4+2*b4)
   yaa4(i)=max(min(abs(1/(1+(((x1(i)-c4)/a4)^(2*b4)))),1),0);
end
if (x1(i)>=c5-2*b5) && (x1(i)<=c5+2*b5)
   yaa5(i)=max(1/(1+(((x1(i)-cc5)/aa5)^(2*bb5)))),1/(1+(((x1(i)-cc4)/aa4)^(2*bb4)));
   yaa5(i)=max(min(yaa5(i),1),0);
end
%************************

%*************************

if (x1(i)>=4.3) && (x1(i)<5)
   ya5(i)=max(min(abs(1/(1+(((x1(i)-cc5)/aa5)^(2*bb5)))),1),0);
end
if (x1(i)>=4.3) && (x1(i)<=5)
   ya5(i)=1;
   yaa5(i)=1;
end

%-------------------------------------------------------------

% drawing the changed figure
if (x2(i)>=c6-2*b6) && (x2(i)<=c6+2*b6)
  ybb1(i)=max(min(abs(1/(1+(((x2(i)-c6)/a6)^(2*b6)))),1),0);
end
% drawing initial figure
if (x2(i)>=1) && (x2(i)<1.35)
  yb1(i)=max(min(1/(1+(((x2(i)-cc6)/aa6)^(2*bb6))),1),0);
end
if (x2(i)>=1) && (x2(i)<=1.25)
  yb1(i)=1;
  ybb1(i)=1;
end
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
if (x2(i)>=1.25) && (x2(i)<=1.6)
   yb2(i)=max(min(abs(1/(1+(((x2(i)-cc7)/aa7)^(2*bb7)))),1),0);
end
if (x2(i)>=c7-2*b7) && (x2(i)<=c7+2*b7)
   ybb2(i)=max(min(abs(1/(1+(((x2(i)-c7)/a7)^(2*b7)))),1),0);
end
if (x2(i)>=c8-2*b8) && (x2(i)<=c8+2*b8)
   ybb3(i)=max(1/(1+(((x2(i)-cc8)/aa8)^(2*bb8)))),1/(1+(((x2(i)-cc8)/aa8)^(2*bb8)));
end
%******************
if (x2(i)>=1.5) && (x2(i)<=2)
   yb3(i)=max(min(abs(1/(1+(((x2(i)-cc8)/aa8)^(2*bb8)))),1),0);
end
if (x2(i)>=c8-2*b8) && (x2(i)<=c8+2*b8)
```

```
    ybb3(i)=max(min(abs(1/(1+(((x2(i)-c8)/a8)^(2*b8)))),1),0);
end
if (x2(i)>=c9-2*b9) && (x2(i)<=c9+2*b9)
    ybb4(i)=max(1/(1+(((x2(i)-cc9)/aa9)^(2*bb9)))),1/(1+(((x2(i)-cc8)/aa8)^(2*bb8)));
end
%*********************
if (x2(i)>=1.9) && (x2(i)<=2.4)
    yb4(i)=max(min(abs(1/(1+(((x2(i)-cc9)/aa9)^(2*bb9)))),1),0);
end
if (x2(i)>=c9-2*b9) && (x2(i)<=c9+2*b9)
    ybb4(i)=max(min(abs(1/(1+(((x2(i)-c9)/a9)^(2*b9)))),1),0);
end
if (x2(i)>=c10-2*b10) && (x2(i)<=c10+2*b10)
    ybb5(i)=max(1/(1+(((x2(i)-cc10)/aa10)^(2*bb10)))),1/(1+(((x2(i)-cc9)/aa9)^(2*bb9)));
    ybb5(i)=max(min(ybb5(i),1),0);
end
%************************

%*************************

if (x2(i)>=2.3) && (x2(i)<2.5)
    yb5(i)=max(min(abs(1/(1+(((x2(i)-cc10)/aa10)^(2*bb10)))),1),0);
end
if (x2(i)>=2.3) && (x2(i)<=2.5)
    yb5(i)=1;
    ybb5(i)=1;
end

%-------------------------------------------------------------

end;

%subplot(2,1,1);plot(x1,ya1,x1,ya2,x1,ya3,x1,ya4,x1,ya5);
subplot(2,1,1);plot(x2,yb1,x2,yb2,x2,yb3,x2,yb4,x2,yb5);
%subplot(2,1,1);plot(x1,yaa1,x1,yaa2,x1,yaa3,x1,yaa4,x1,yaa5,x1,ya1,x1,ya2,x1,ya3,x1,ya4,x1,ya5);
%subplot(2,1,2);plot(x2,ybb1,x2,ybb2,x2,ybb3,x2,ybb4,x2,ybb5,x2,yb1,x2,yb2,x2,yb3,x2,yb4,x2,yb5);
%subplot(2,1,2);plot(x1,yaa1,x1,yaa2,x1,yaa3,x1,yaa4,x1,yaa5);
subplot(2,1,2);plot(x2,ybb1,x2,ybb2,x2,ybb3,x2,ybb4,x2,ybb5);

%these are input and output

m=1;
l=1;

x3=[3.3 3 2.9 2.8 2.75 4.2 3.6 3.4 3.3 3.25 4.6 3.9 3.8 3.75 3.7 4.8 4.35 4.25 4.2 4.15 4.8 4.79 4.78 4.77
4.76];
x4=[2.1 1.4 1.35 1.3 1.25 2.25 1.65 1.55 1.45 1.4 1.75 1.8 1.85 2 2.4 2.2 2.25 2.3 2.35 2.45 2.46 2.47
2.48 2.49 2.5 ];

x5=[2.5 2.5 2.5 2.5 2.5 2.5 2.5 2.5 2.5 2.5 2.8 3.4 3.45 3.5 3.6 3.25 3.75 3.8 3.85 3.9 4.25 4.26 4.27 4.28
4.29];
x6=[1 1 1 1 1 1 1.1 1.15 1.2 1.25 1 1.35 1.55 1.75 1.7 1.2 1.75 1.8 1.85 1.9 2.25 2.26 2.27 2.28 2.29];

for i=1:25
    for j=1:25
yra1=0;
yraa1=0;
yra2=0;
yraa2=0;
yra3=0;
```

```
yraa3=0;
yra4=0;
yraa4=0;
yra5=0;
yraa5=0;

yrb1=0;
yrbb1=0;
yrb2=0;
yrbb2=0;
yrb3=0;
yrbb3=0;
yrb4=0;
yrbb4=0;
yrb5=0;
yrbb5=0;

if (x3(i)>=c1-2*b1) && (x3(i)<=c1+2*b1)
   yraa1=max(min(abs(1/(1+(((x3(i)-c1)/a1)^(2*b1)))),1),0);
end
% drawing initial figure
if (x3(i)>=2.5) && (x3(i)<3.2)
   yra1=max(min(1/(1+(((x3(i)-cc1)/aa1)^(2*bb1))),1),0);
end
if (x3(i)>=2.5) && (x3(i)<=3)
  yra1=1;
  yraa1=1;
end
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
if (x3(i)>=3.1) && (x3(i)<=3.6)
   yra2=max(min(abs(1/(1+(((x3(i)-cc2)/aa2)^(2*bb2)))),1),0);
end
if (x3(i)>=c2-2*b2) && (x3(i)<=c2+2*b2)
   yraa2=max(min(abs(1/(1+(((x3(i)-c2)/a2)^(2*b2)))),1),0);
end
if (x3(i)>=c3-2*b3) && (x3(i)<=c3+2*b3)
   yraa3=max(1/(1+(((x3(i)-cc3)/aa3)^(2*bb3)))),1/(1+(((x3(i)-cc2)/aa2)^(2*bb2)));
end
%******************
if (x3(i)>=3.5) && (x3(i)<=4)
   yra3=max(min(abs(1/(1+(((x3(i)-cc3)/aa3)^(2*bb3)))),1),0);
end
if (x3(i)>=c3-2*b3) && (x3(i)<=c3+2*b3)
   yraa3=max(min(abs(1/(1+(((x3(i)-c3)/a3)^(2*b3)))),1),0);
end
if (x3(i)>=c4-2*b4) && (x3(i)<=c4+2*b4)
   yraa4=max(1/(1+(((x3(i)-cc4)/aa4)^(2*bb4)))),1/(1+(((x3(i)-cc3)/aa3)^(2*bb3)));
end
%*********************
if (x3(i)>=3.9) && (x3(i)<=4.4)
   yra4=max(min(abs(1/(1+(((x3(i)-cc4)/aa4)^(2*bb4)))),1),0);
end
if (x3(i)>=c4-2*b4) && (x3(i)<=c4+2*b4)
   yraa4=max(min(abs(1/(1+(((x3(i)-c4)/a4)^(2*b4)))),1),0);
end
if (x3(i)>=c5-2*b5) && (x3(i)<=c5+2*b5)
   yraa5=max(1/(1+(((x3(i)-cc5)/aa5)^(2*bb5)))),1/(1+(((x3(i)-cc4)/aa4)^(2*bb4)));
   yraa5=max(min(yaa5(i),1),0);
end
%************************

%************************
```

```
if (x3(i)>=4.3) && (x3(i)<5)
    yra5=max(min(abs(1/(1+(((x3(i)-cc5)/aa5)^(2*bb5)))),1),0);
end
if (x3(i)>=4.3) && (x3(i)<=5)
    yra5=1;
    yraa5=1;
end

%-------------------------------------------------------------

% drawing the changed figure
if (x4(j)>=c6-2*b6) && (x4(j)<=c6+2*b6)
   yrbb1=max(min(abs(1/(1+(((x4(j)-c6)/a6)^(2*b6)))),1),0);
end
% drawing initial figure
if (x4(j)>=1) && (x4(j)<1.35)
   yrb1=max(min(1/(1+(((x4(j)-cc6)/aa6)^(2*bb6))),1),0);
end
if (x4(j)>=1) && (x4(j)<=1.25)
   yrb1=1;
   yrbb1=1;
end
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
if (x4(j)>=1.25) && (x4(j)<=1.6)
    yrb2=max(min(abs(1/(1+(((x4(j)-cc7)/aa7)^(2*bb7)))),1),0);
end
if (x4(j)>=c7-2*b7) && (x4(j)<=c7+2*b7)
    yrbb2=max(min(abs(1/(1+(((x4(i)-c7)/a7)^(2*b7)))),1),0);
end
if (x4(j)>=c8-2*b8) && (x4(j)<=c8+2*b8)
    yrbb3=max(1/(1+(((x4(i)-cc8)/aa8)^(2*bb8)))),1/(1+(((x4(i)-cc8)/aa8)^(2*bb8)));
end
%*******************
if (x4(j)>=1.5) && (x4(j)<=2)
    yrb3=max(min(abs(1/(1+(((x4(j)-cc8)/aa8)^(2*bb8)))),1),0);
end
if (x4(j)>=c8-2*b8) && (x4(j)<=c8+2*b8)
    yrbb3=max(min(abs(1/(1+(((x4(j)-c8)/a8)^(2*b8)))),1),0);
end
if (x4(j)>=c9-2*b9) && (x4(j)<=c9+2*b9)
    yrbb4=max(1/(1+(((x4(j)-cc9)/aa9)^(2*bb9)))),1/(1+(((x4(j)-cc8)/aa8)^(2*bb8)));
end
%**********************
if (x4(j)>=1.9) && (x4(j)<=2.4)
    yrb4=max(min(abs(1/(1+(((x4(j)-cc9)/aa9)^(2*bb9)))),1),0);
end
if (x4(j)>=c9-2*b9) && (x4(j)<=c9+2*b9)
    yrbb4=max(min(abs(1/(1+(((x4(j)-c9)/a9)^(2*b9)))),1),0);
end
if (x4(j)>=c10-2*b10) && (x4(j)<=c10+2*b10)
    yrbb5=max(1/(1+(((x4(j)-cc10)/aa10)^(2*bb10)))),1/(1+(((x4(j)-cc9)/aa9)^(2*bb9)));
    yrbb5=max(min(yrbb5,1),0);
end
%************************

%************************

if (x4(j)>=2.3) && (x4(j)<2.5)
    yrb5=max(min(abs(1/(1+(((x4(j)-cc10)/aa10)^(2*bb10)))),1),0);
end
```

```
if (x4(j)>=2.3) && (x4(j)<=2.5)
    yrb5=1;
    yrbb5=1;
end


% rules: definging the rules for each variables for example w1= ya1(good)*yb1(good)
w(1)=yraa1*yrbb1;
w(2)=yraa1*yrbb2;
w(3)=yraa1*yrbb3;
w(4)=yraa1*yrbb4;
w(5)=yraa1*yrbb5;

w(6)=yraa2*yrbb1;
w(7)=yraa2*yrbb2;
w(8)=yraa2*yrbb3;
w(9)=yraa2*yrbb4;
w(10)=yraa2*yrbb5;

w(11)=yraa3*yrbb1;
w(12)=yraa3*yrbb2;
w(13)=yraa3*yrbb3;
w(14)=yraa3*yrbb4;
w(15)=yraa3*yrbb5;

w(16)=yraa4*yrbb1;
w(17)=yraa4*yrbb2;
w(18)=yraa4*yrbb3;
w(19)=yraa4*yrbb4;
w(20)=yraa4*yrbb5;

w(21)=yraa5*yrbb1;
w(22)=yraa5*yrbb2;
w(23)=yraa5*yrbb3;
w(24)=yraa5*yrbb4;
w(25)=yraa5*yrbb5;

%************************************
wa(1)=yra1*yrb1;
wa(2)=yra1*yrb2;
wa(3)=yra1*yrb3;
wa(4)=yra1*yrb4;
wa(5)=yra1*yrb5;

wa(6)=yra2*yrb1;
wa(7)=yra2*yrb2;
wa(8)=yra2*yrb3;
wa(9)=yra2*yrb4;
wa(10)=yra2*yrb5;

wa(11)=yra3*yrb1;
wa(12)=yra3*yrb2;
wa(13)=yra3*yrb3;
wa(14)=yra3*yrb4;
wa(15)=yra3*yrb5;

wa(16)=yra4*yrb1;
wa(17)=yra4*yrb2;
wa(18)=yra4*yrb3;
wa(19)=yra4*yrb4;
```

```
wa(20)=yra4*yrb5;

wa(21)=yra5*yrb1;
wa(22)=yra5*yrb2;
wa(23)=yra5*yrb3;
wa(24)=yra5*yrb4;
wa(25)=yra5*yrb5;

% the function for each rule(zero-order sugeno)
f(1)= 0.7;
f(2)= 0.6;
f(3)= 0.9;
f(4)= 0.9;
f(5)= 0.8;
f(6)= 0.75;
f(7)= 0.8;
f(8)= 0.6;
f(9)= 0.8;
f(10)= 0.7;
f(11)= 0.6;
f(12)= 0.9;
f(13)= 0.9;
f(14)= 0.8;
f(15)= 0.75;
f(16)= 0.8;
f(17)= 0.6;
f(18)= 0.8;
f(19)= 0.7;
f(20)= 0.6;
f(21)= 0.9;
f(22)= 0.9;
f(23)= 0.8;
f(24)= 0.75;
f(25)= 0.8;

sum=w(1)+w(2)+w(3)+w(4)+w(5)+w(6)+w(7)+w(8)+w(9)+w(10)+w(11)+w(12)+w(13)+w(14)+w(15)
+w(16)+w(17)+w(18)+w(19)+w(20)+w(21)+w(22)+w(23)+w(24)+w(25)+1;
suma=wa(1)+wa(2)+wa(3)+wa(4)+wa(5)+wa(6)+wa(7)+wa(8)+wa(9)+wa(10)+wa(11)+wa(12)+wa(13
)+wa(14)+wa(15)+wa(16)+wa(17)+wa(18)+wa(19)+wa(20)+wa(21)+wa(22)+wa(23)+wa(24)+wa(25)+
1;

for l=1:25
   wn1(l)= (w(l))/sum;
   wy1(l)=f(l)*wn1(l);

   wna1(l)= (wa(l))/suma;
   wya1(l)=f(l)*wna1(l);

end
sum2=wy1(1)+wy1(2)+wy1(3)+wy1(4)+wy1(5)+wy1(6)+wy1(7)+wy1(8)+wy1(9)+wy1(10)+wy1(11)+
wy1(12)+wy1(13)+wy1(14)+wy1(15)+wy1(16)+wy1(17)+wy1(18)++wy1(19)+wy1(20)+wy1(21)+wy
1(22)+wy1(23)+wy1(24)+wy1(25);
y=sum2;
% define the wich rule fired
resultd=0;
result=max(wy1);
for n=1:25
   if wy1(n)==result
      resultd=n;
   end;
end;
```

```
alpha(m)=result; %%%%the result in alpha cut for matlab
a(m,1)=x3(i)*x4(j);
a(m,2)=x5(i)*x6(j);
a(m,3)=6;
a(m,4)=5;
a(m,5)=7;
a(m,6)=4;
a(m,7)=1;
a(m,8)=2;
a(m,9)=3;
a(m,10)=1600;
a(m,11)=600;
a(m,12)=4;
a(m,13)=2;
a(m,14)=1;
a(m,15)=6;
a(m,16)=7;
a(m,17)=5;
a(m,18)=3;
a(m,19)=alpha(m);
m=m+1;
end ;
end;
```

Optimisation phase Code

```
%**************************************
%solve problem for 625 scenarios
%**************************************
% Variables for Robust Optimisation model
global landa;
global a;
global omega;
global p;
global t;
global pl;
global g;
global cc;
global toc;
global y0;
global ffg;
global alphacut1;
 y0=[68 4310 300 950 1860 2450 3970 370 100 100 90 123 98 120 100 100 120 10 100 170 100 100
100 50 100 100 80 100 100 100 120 110 100 100 100 80 90 80 70 80 90 100 80 70 80 90 100 100 102
110 120 130 120 110 100 100 100 100 100 110 110 110 120 100 120 80 90 80 70 80 80 90 80 70 80 90
100 100 120 120 130 90 70 80 100 103 105 80 90 110 100 80 100 100 30 20 40 10 10 10 10 12 15 10
10 10 12 15 14 12 13 12 12 15 12 16 17 20 15 18 19 20 21 25 16 18 19 20 12 15 14 15 18 19 18 12 11
10 10 10 10 10 16 16 15 14 12 13 12 12 15 14 18 19 16 10 12 14 16 18 19 10 10 10 15 18 17 16 18 10
10 10 10 15 18 17 16 15 10 10 10 10 10 12 13 16 20 12 13 15 16 12 10 10 10 15 12 10 10 10 12 15 10 9
12 14 16 12 100 300 120 100 225 235 262 300 120 100 50 90 80 70 60 50 50 50 50 40 20 30 20 10 50
10 10 20 10 30 10 20 10 ];
%landfillgas ccg biomass wind OIL COAL gas solar
cc=[107.5 11.75 50.18 28.51 11.40 25.91 11.01 10.99];% fixed cost for each resource
cc=cc*1000;
%landfillgas  ccg  biomass wind   OIL COAL gas  solar
toc=[0.001 1.940 2.960  0.001 3.36 4.32 1.88 0.001 ];% operation cost for each resource
toc=toc*1000;
%**************Load factor=average/peak
lf=0.8094;
%**************
%each scenario
%it should be defined by alpha cut from ANFIS
%**************************************
%optimise first stage model based on different alpha cut
for k=1:625
ff(k)=lp(a(k,1),a(k,2),a(k,3),a(k,4),a(k,5),a(k,6),a(k,7),a(k,8),a(k,9),a(k,10),a(k,11),a(k,12),a(k,13),a(k,1
4),a(k,15),a(k,16),a(k,17),a(k,18),a(k,19));
ffg(k)=ff(k);
end;
%**************************************
%**************************************
%finding the best answer for each scenario (different alpha cut(5 alpha cuts))
k=0;
%alphacut1=zeros(1,625);
for j=1:25:625
k=1+k;
alphacut1(k)=max(ffg(j:j+24));
end;
%**************************************
k=1;
% picking up the t , ppl from a matrix .... scenarios %
for i=1:625
  if ff(i)==alphacut1(k)
     t(k)=a(i,1);
     t1(k)=a(i,2);
     pl(k)=a(i,10)*0.01;
```

```
        pl1(k)=a(i,11)*0.01;
        % Growth rate for WA
        g(k)=t(k)*pl(k);
        g1(k)=t1(k)*pl1(k);
        p(k)=a(i,19);
        if k ~= 25
        k=k+1;
        end
    end
end;

x=zeros(241,1);% 8+8*25+8+25
excess=zeros(10,10);
landa=0;
for tt=1:5
    ff=0;
    omega=0;
for l=1:5
%**************************************
%Aeq=zeros(25,214);%(s,r)
A=zeros(50,241);%(r,x)
for i=1:8 %2 is the number of resources
 A(i,i)=-1;
 c=1;
 A(i,c+8)=1;
 A(i,c+9)=1;
 A(i,c+10)=1;
 A(i,c+11)=1;
 A(i,c+12)=1;
 A(i,c+13)=1;
 A(i,c+14)=1;
 A(i,c+15)=1;
 A(i,c+16)=1;
 A(i,c+17)=1;
 A(i,c+18)=1;
 A(i,c+19)=1;
 A(i,c+20)=1;
 A(i,c+21)=1;
 A(i,c+22)=1;
 A(i,c+23)=1;
 A(i,c+24)=1;
 A(i,c+25)=1;
 A(i,c+26)=1;
 A(i,c+27)=1;
 A(i,c+28)=1;
 A(i,c+29)=1;
 A(i,c+30)=1;
 A(i,c+31)=1;
 A(i,c+32)=1;
 c=c+25;
 A(i,8+8*25+i)=1;
end
sc=1;%for scenarios in loop
c=1;
for i=9:33 %
 A(i,c+8)=-1;
 A(i,c+33)=-1;
 A(i,c+58)=-1;
 A(i,c+83)=-1;
 A(i,c+108)=-1;
 A(i,c+133)=-1;
 A(i,c+158)=-1;
```

```
 A(i,c+183)=-1;
 if c ~= 25
   c=c+1;
 end
 %A(i,i+7+25)=g(sc);
 A(i,8+8*25+i)=-1;%5 number of variables + 2 number of resources
end
% resource limitation
c=0;
for i=1:8
 A(34+c,i)=1;
 c=c+1;
end;
%renewable enrgy for each resource
A(42,8)=-1;
A(42,1)=-1;
A(42,3)=-1;
A(42,4)=-1;
%***********************************
%***********************************
c=0;
for i=1:8
   A(43+c,208+i)=1;
   c=c+1;
end

%*********************************
% making beq matrix
for i=1:8 % number of resources (2)
b(i)=0;
end
c=1;
for i=9:33 % number of resources (2)+1
%beq(i)=t(i)*pl(i);
b(i)=-g(c)*30;
  if c ~= 25
     c=c+1;
  end
end
%resource limitation
%landfillgas  ccg solar wind   OIL COAL gas   biomass
b(34)=50;
b(35)=3000;
b(36)=200;
b(37)=600;
b(38)=600;
b(39)=500;
b(40)=3300;
b(41)=40;
%renewable energy limitation
b(42)=-g(c)*30*0.1;
%**************
%load factor
c=1;
for i=43:50
b(i)=(2-lf)*30*g(c);
c=c+1;
end
%*********************************
y0=y0-(y0*(0.03));
y0(209)=y0(209)-y0(209)*0.001;
y0(210)=y0(210)-y0(210)*0.001;
```

```
y0(211)=y0(211)-y0(211)*0.001;
y0(212)=y0(212)-y0(212)*0.001;
y0(213)=y0(213)-y0(213)*0.001;
y0(214)=y0(214)-y0(214)*0.001;
y0(215)=y0(215)-y0(215)*0.001;
y0(216)=y0(216)-y0(216)*0.001;
lb =zeros(241,1);
% Start with the default options
options = optimset;
% Modify options setting
options = optimset(options,'LargeScale' ,'on');
%options = optimset(options,'TolX',1e-3,'TolFun',1e-3);
y=fmincon(@objfunc910,y0,A,b,[],[],lb,[],[],options);
%**********************************
%******find solution for each scenario
for k=1:25
   for i=1:8
      ff(k,l)= cc(i)*y(i);
   end
end

for k=1:25
   k1=k+9;
   for i=1:8
      ff(k,l)= toc(i)*y(k1)+ff(k,l);
      k1=k1+25;
   end
end
k1=8+25*8+1;

for i=1:8%(2+3 -1)
     excess(tt,l)=(y(k1))+excess(tt,l);
   k1=k1+1;
end
omega=omega+200;
end
ff=ff*.001;
 ave=mean(ff,1);
stdev=std(ff,0,1);
 for i=1:5
   avet(tt,i)=ave(1,i);
   stedvt(tt,i)=stdev(1,i);
end
landa=landa+0.2;
end
```