# *Matlab Code for the first Case Study in Chapter 6*

```
clear;
h=1;
sum=0;
ya=zeros(4,3);
y=zeros(1,4);
yb=zeros(4,9);


sumc=0;
yac=zeros(4,3);
yc=zeros(1,4);
ybc=zeros(4,9);

r=zeros(1,300);
% Seting the first value of variables
da1=0;
da2=0;
da3=0;
da4=0;
da5=0;
da6=0;
db1=0;
db2=0;
db3=0;
db4=0;
db5=0;
db6=0;
dc1=0;
dc2=0;
dc3=0;
dc4=0;
dC5=0;
dC6=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=-1/2;
b1=2;
a1=0.25;

c2=0;
b2=2;
a2=0.25;

c3=1/2;
b3=2;
a3=0.25;

c4=22.5;
b4=2;
a4=1.25;

c5=25;
b5=2;
a5=1.25;


c6=27.5;
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b6=2;
a6=1.25;


%training data
tdata=[-1 20.5 0 0 0.1 0 0 0 0 0 0;0.6 28 0 0 0.1 0 0 0 0 0 0;0.4 22 0 0 0.1 0 0 0 0 0 0;0.50 27 0 0 0.1 0 0
0 0 0 0];
%checking data
cdata=[-0.9 20 0 0 0.1 0 0 0 0 0 0;0.6 27 0 0 0.1 0 0 0 0 0 0;0.4 23 0 0 0.1 0 0 0 0 0 0;0.40 27 0 0 0.1 0 0
0 0 0 0];

% 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=[0.2 0.25 0.4 0.55];
ydc=[0.3 0.35 0.5 0.65];
yd1(k)=max(yd);
e=0;
% finding the membership function of x1 , x2 based on the triangular
% function (ai , bi are changing during learning algorithm)
if (x1>=-1) && (x1<=0)
     ya(k,1)=abs(1/(1+(((x1-c1)/a1).^(2*b1))));
     yac(k,1)=abs(1/(1+(((xc1-c1)/a1).^(2*b1))));

end

if (x1>=-0.5) && (x1<=0.5)
   ya(k,2)=abs(1/(1+(((x1-c2)/a2).^(2*b2))));
   yac(k,2)=abs(1/(1+(((xc1-c2)/a2).^(2*b2))));
end
if (x1>=0) && (x1<1)
   ya(k,3)=abs(1/(1+(((x1-c3)/a3).^(2*b3))));
   yac(k,3)=abs(1/(1+(((xc1-c3)/a3).^(2*b3))));
end
if (x2>=20) && (x2<=25)
   yb(k,1)=abs(1/(1+(((x2-c4)/a4).^(2*b4))));
   ybc(k,1)=abs(1/(1+(((xc2-c4)/a4).^(2*b4))));
end
if (x2>=22.5) && (x2<=27.5)
   yb(k,2)=abs(1/(1+(((x2-c5)/a5).^(2*b5))));
   ybc(k,2)=abs(1/(1+(((xc2-c5)/a5).^(2*b5))));
end
if (x2>=25) && (x2<=30)
   yb(k,3)=abs(1/(1+(((x2-c6)/a6).^(2*b6))));
   ybc(k,3)=abs(1/(1+(((xc2-c6)/a6).^(2*b6))));

end

% rules: definging the rules for each variables for example w1= ya1(good)*yb1(good)
w(1)=ya(k,1)*yb(k,1);
w(2)=ya(k,1)*yb(k,2);
w(3)=ya(k,1)*yb(k,3);

w(4)=ya(k,2)*yb(k,1);
w(5)=ya(k,2)*yb(k,2);
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w(6)=ya(k,2)*yb(k,3);

w(7)=ya(k,3)*yb(k,1);
w(8)=ya(k,3)*yb(k,2);
w(9)=ya(k,3)*yb(k,3);

wc(1)=yac(k,1)*ybc(k,1);
wc(2)=yac(k,1)*ybc(k,2);
wc(3)=yac(k,1)*ybc(k,3);

wc(4)=yac(k,2)*ybc(k,1);
wc(5)=yac(k,2)*ybc(k,2);
wc(6)=yac(k,2)*ybc(k,3);

wc(7)=yac(k,3)*ybc(k,1);
wc(8)=yac(k,3)*ybc(k,2);
wc(9)=yac(k,3)*ybc(k,3);



for i= 1:9
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)= 0.5;
f(5)= 0.3;
f(6)= 0.8;
f(7)= 0.8;
f(8)= 0.6;
f(9)= 0.8;

% first of epoch for learning algorithm
w1=w;
% the number of epoch
maxcycle=3000;
% the learning rate
alpha=.02;
%the acceptance erorr
ssegoal=.005;
for m=1:maxcycle
   for i= 1:4
   sum(i)=tw(i,1)+tw(i,2)+tw(i,3)+tw(i,4)+tw(i,5)+tw(i,6)+tw(i,7)+tw(i,8)+tw(i,9)+1;
   sumc(i)=twc(i,1)+twc(i,2)+twc(i,3)+twc(i,4)+twc(i,5)+twc(i,6)+twc(i,7)+twc(i,8)+twc(i,9)+1;
   end;

for j=1:4
   y(j)=0;
   yc(j)=0;
for i=1:9
   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);
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    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=1:9;
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))*(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))*(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))*(ya(j,1)*ya(j,1)*2*b1*((x1-c1)/a1)^(2*b1-1))*yb(j,1);

da2=(tw(j,4)+tw(j,5)+tw(j,6))*((2*b2*ya(j,2)*ya(j,2)*(x1-c2)^(2*b2))/a1^(2*b2+1))*yb(j,2);
db2=(tw(j,4)+tw(j,5)+tw(j,6))*(exp(x1-c2)*2*a2^(2*b2)/(a2.^(2*b2)+(x1-c2)^(2*b2)))*yb(j,2);
dc2=(tw(j,4)+tw(j,5)+tw(j,6))*(ya(j,2)*ya(j,2)*2*b2*((x1-c2)/a2)^(2*b2-1))*yb(j,2);

da3=(tw(j,7)+tw(j,8)+tw(j,9))*((2*b3*ya(j,3)*ya(j,3)*(x1-c3)^(2*b3))/a3^(2*b3+1))*yb(j,3);
db3=(tw(j,7)+tw(j,8)+tw(j,9))*(exp(x1-c3)*2*a3^(2*b3)/(a3^(2*b3)+(x1-c3)^(2*b3)))*yb(j,3);
dc3=(tw(j,7)+tw(j,8)+tw(j,9))*(ya(j,3)*ya(j,3)*2*b3*((x1-c3)/a3)^(2*b3-1))*yb(j,3);

da4=(tw(j,1)+tw(j,2)+tw(j,3))*((2*b4*yb(j,1)*yb(j,1)*(x2-c4)^(2*b4))/a4^(2*b4+1))*ya(j,1);
db4=(tw(j,1)+tw(j,2)+tw(j,3))*(exp(x2-c4)*2*a4^(2*b4)/(a4^(2*b4)+(x2-c4)^(2*b4)))*ya(j,1);
dc4=(tw(j,1)+tw(j,2)+tw(j,3))*(yb(j,1)*yb(j,1)*2*b4*((x2-c4)/a4)^(2*b4-1))*ya(j,1);

da5=(tw(j,4)+tw(j,5)+tw(j,6))*((2*b5*yb(j,2)*yb(j,2)*(x2-c5)^(2*b5))/a5^(2*b5+1))*ya(j,2);
db5=(tw(j,4)+tw(j,5)+tw(j,6))*(exp(x2-c5)*2*a5^(2*b5)/(a5^(2*b5)+(x2-c5)^(2*b5)))*ya(j,2);
dc5=(tw(j,4)+tw(j,5)+tw(j,6))*(yb(j,2)*yb(j,2)*2*b5*((x2-c5)/a5)^(2*b5-1))*ya(j,2);

da6=(tw(j,7)+tw(j,8)+tw(j,9))*((2*b6*yb(j,3)*yb(j,3)*(x2-c6)^(2*b6))/a6^(2*b6+1))*ya(j,3);
db6=(tw(j,7)+tw(j,8)+tw(j,9))*(exp(x2-c6)*2*a6^(2*b6)/(a6^(2*b6)+(x2-c6)^(2*b6)))*ya(j,3);
dc6=(tw(j,7)+tw(j,8)+tw(j,9))*(yb(j,3)*yb(j,3)*2*b6*((x2-c6)/a6)^(2*b6-1))*ya(j,3);


a1=a1+da1;
a2=a2+da2;
a3=a3+da3;
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a4=a4+da4;
a5=a5+da5;
a6=a6+da6;
b1=b1+db1;
b2=b2+db2;
b3=b3+db3;
b4=b4+db4;
b5=b5+db5;
b6=b6+db6;
c1=c1+dc1;
c2=c2+dc2;
c3=c3+dc3;
c4=c4+dc4;
c5=c5+dc5;
c6=c6+dc6;

end;

%drawing the new figure based on the learning data and change ai and bi

x1=[-1:0.01:1];
x2=[20:0.05:30];
yaa1=zeros(length(x1));
yaa2=zeros(length(x1));
yaa3=zeros(length(x1));

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

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

yb1=zeros(length(x1));
yb2=zeros(length(x1));
yb3=zeros(length(x1));

cc1=-1/2;
bb1=2;
aa1=0.25;

cc2=0;
bb2=2;
aa2=0.25;

cc3=1/2;
bb3=2;
aa3=0.25;

cc4=22.5;
bb4=2;
aa4=1.25;

cc5=25;
bb5=2;
aa5=1.25;


cc6=27.5;
bb6=2;
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aa6=1.25;


for i=1:201
% drawing the changed figure
if (x1(i)>=c1-2*a1) && (x1(i)<=c1+2*a1)
    yaa1(i)=abs(1/(1+(((x1(i)-c1)/a1)^(2*b1))));
end
% drawing initial figure
if (x1(i)>=-1) && (x1(i)<=0)
   ya1(i)=max(min(abs(1/(1+(((x1(i)-cc1)/aa1)^(2*bb1)))),1),0);
 end

if (x1(i)>=-0.5) && (x1(i)<=0.5)
    ya2(i)=max(min(abs(1/(1+(((x1(i)-cc2)/aa2)^(2*bb2)))),1),0);
end
if (x1(i)>=c2-2*a2) && (x1(i)<=c2+2*a2)
    yaa2(i)=max(min(abs(1/(1+(((x1(i)-c2)/a2)^(2*b2)))),1),0);
end

if (x1(i)>=c3-2*a3) && (x1(i)<=c3+2*a3)
    yaa3(i)=max(min(abs(1/(1+(((x1(i)-c3)/a3)^(2*b3)))),1),0);
end
if (x1(i)>=0) && (x1(i)<=1)
    ya3(i)=max(min(abs(1/(1+(((x1(i)-cc3)/aa3)^(2*bb3)))),1),0);
end

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

if (x2(i)>=c4-2*a4) && (x2(i)<=c5+2*a5)
   ybb1(i)=max(min(abs(1/(1+(((x2(i)-c4)/a4)^(2*b4)))),1),0);
end
if (x2(i)>=20) && (x2(i)<=25)
   yb1(i)=max(min(abs(1/(1+(((x2(i)-cc4)/aa4)^(2*bb4)))),1),0);

end
if (x2(i)>c5-2*a5) && (x2(i)<=c5+2*a5)
    ybb2(i)=max(min(abs(1/(1+(((x2(i)-c5)/a5)^(2*b5)))),1),0);
end;
if (x2(i)>22.5) && (x2(i)<=27.5)
    yb2(i)=max(min(abs(1/(1+(((x2(i)-cc5)/aa5)^(2*bb5)))),1),0);
end;

if (x2(i)>c6-2*a6) && (x2(i)<=c6+2*a6)
    ybb3(i)=max(min(abs(1/(1+(((x2(i)-c6)/a6)^(2*b6)))),1),0);
end;
if (x2(i)>25) && (x2(i)<=30)
    yb3(i)=max(min(abs(1/(1+(((x2(i)-cc6)/aa6)^(2*bb6)))),1),0);
end;

end;
subplot(2,1,2); plot(x1,yaa1,x1,yaa2,x1,yaa3);
subplot(2,1,1); plot(x1,ya1,x1,ya2,x1,ya3);

%these are input and output
x1=-0.1;%answer{1,1};%
x2=21.5;%answer{2,1};%
yra1=0;
yra2=0;
yra3=0;
yrb1=0;
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```
yrb2=0;
yrb3=0;
if (x1>=-1) && (x1<=0)
     yra1=abs(1/(1+(((x1-c1)/a1).^(2*b1))));
end
if (x1>=-0.5) && (x1<=0.5)
   yra2=abs(1/(1+(((x1-c2)/a2).^(2*b2))));
end
if (x1>=0) && (x1<1)
   yra3=abs(1/(1+(((x1-c3)/a3).^(2*b3))));
end
if (x2>=20) && (x2<=25)
   yrb1=abs(1/(1+(((x2-c4)/a4).^(2*b4))));
end
if (x2>=22.5) && (x2<=27.5)
   yrb2=abs(1/(1+(((x2-c5)/a5).^(2*b5))));
end
if (x2>=25) && (x2<=30)
   yrb3=abs(1/(1+(((x2-c6)/a6).^(2*b6))));
end

% rules: definging the rules for each variables for example w1= ya1(good)*yb1(good)
w(1)=yra1*yrb1;
w(2)=yra1*yrb2;
w(3)=yra1*yrb3;

w(4)=yra2*yrb1;
w(5)=yra2*yrb2;
w(6)=yra2*yrb3;

w(7)=yra3*yrb1;
w(8)=yra3*yrb2;
w(9)=yra3*yrb3;


% the function for each rule(zero-order sugeno)
f(1)= 0.7;
f(2)= 0.6;
f(3)= 0.9;
f(4)= 0.5;
f(5)= 0.3;
f(6)= 0.8;
f(7)= 0.8;
f(8)= 0.6;
f(9)= 0.8;

sum=w(1)+w(2)+w(3)+w(4)+w(5)+w(6)+w(7)+w(8)+w(9)+1;
for i=1:9
   wn1(i)= (w(i))/sum;
   wy1(i)=f(i)*wn1(i);
end
sum2=wy1(1)+wy1(2)+wy1(3)+wy1(4)+wy1(5)+wy1(6)+wy1(7)+wy1(8)+wy1(9);
y=sum2;

% define the wich rule fired
resultd=0;

result=max(wn1);
for i=1:9
   if wn1(i)==result
      resultd=i;
   end;
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end;
if resultd==1
    h = msgbox('do D1 strategic direction') ;
end
if resultd==2
    h = msgbox('do D2 strategic direction') ;
end
if resultd==3
    h = msgbox('do D3 strategic direction') ;
end
if resultd==4
    h = msgbox('do D4 strategic direction') ;
end
if resultd==5
    h = msgbox('do D5 strategic direction') ;
end
if resultd==6
    h = msgbox('do D6 strategic direction') ;
end
if resultd==7
    h = msgbox('do D7 strategic direction') ;
end
if resultd==8
    h = msgbox('do D8 strategic direction') ;
end
if resultd==9
    h = msgbox('do D9 strategic direction') ;
end
```