

## MATLAB Code of Fuzzy Logic Controller:

```
% Two processes controlled by a FUZZY LOGIC CONTROLLER
% Linear system ( First Order instable Model) and nonlinear system
% member ship function (e,er,du) (7x7x7)
% We use only 24 data rules.
% Dr. R. HEDJAR Dec 14,2004.
% CCIS-Computer Eng. Department
```

```
Clear all
```

```
% Time
t=[1:500];
n=length(t);
```

```
%Disturbance Generation
sal=2*randn(1,n);
p=(sal-mean(sal))/n;
```

```
%Desired response
yref=10+5*sign(sin(pi*t/150));
```

```
% Scale factors
Ker=0.5;Kder=0.5;Kout=0.8;
```

```
u(1)=0;y(1)=0;e(1)=0;
a1=-1.15;b1=1;
for k = 2:n,
```

```
    % Non Linear system
    %y(k)=-a1*y(k-1)/(1+y(k-1)^2)+b1*u(k-1)+2*p(k)+p(k-1);
```

```
    %Unstable Linear System
    y(k)=-a1*y(k-1)+b1*u(k-1)+2*p(k)+p(k-1);
```

```
    e(k)=yref(k)-y(k);
    der(k)=e(k)-e(k-1);
    er=Ker*e(k);
    de=Kder*der(k);
    w=zeros(1,24);
    du=zeros(1,24);
```

### **% Rule 1**

```
if (er>=3)&(er<=6)&(de>=-3)&(de<=0)
    w1=(er-3)/3;
    w2=(de+3)/3;
    w(1)=min([w1 w2]);
    du(1)=6;
elseif (er>=3)&(er<=6)&(de>=0)&(de<=3)
    w1=(er-3)/3;
    w2=-(-de-3)/3;
    w(1)=min([w1 w2]);
    du(1)=6;
elseif (er>=6)&(de>=-3)&(de<=0)
    w1=(de+3)/3;
    du(1)=6;
elseif (er>=6)&(de>=0)&(de<=3)
    w1=-(-de-3)/3;
    du(1)=6;
else
    w(1)=0;
    du(1)=0;
```

end

**% Rule 2**

```
if (er>=3)&(er<=6)&(de>=-5)&(de<=-2)
    w1=(er-3)/3;
    w2=(de+5)/3;
    w(2)=min([w1 w2]);
    du(2)=4;
elseif (er>=3)&(er<=6)&(de>=-2)&(de<=1)
    w1=(er-3)/3;
    w2=- (de-1)/3;
    w(2)=min([w1 w2]);
    du(2)=4;
elseif (er>=6)&(de>=-5)&(de<=-2)
    w(2)=(de+5)/3;
    du(2)=4;
elseif (er>=6)&(de>=-2)&(de<=1)
    w(2)=- (de-1)/3;
    du(2)=4;
else
    w(2)=0;
    du(2)=0;
end
```

**% Rule 3**

```
if (er>=1)&(er<=4)&(de>=-6)&(de<=-4)
    w1=(er-1)/3;
    w2=(de+7)/3;
    w(3)=min([w1 w2]);
    du(3)=0;
elseif (er>=1)&(er<=4)&(de>=-4)&(de<=-1)
    w1=(er-1)/3;
    w2=- (de+1)/3;
    w(3)=min([w1 w2]);
    du(3)=0;
elseif (er>=4)&(er<=6)&(de>=-6)&(de<=-4)
    w1=- (er-7)/3;
    w2=(de+7)/3;
    w(3)=min([w1 w2]);
    du(3)=0;
elseif (er>=4)&(er<=6)&(de>=-4)&(de<=-1)
    w1=- (er-7)/3;
    w2=- (de+1)/3;
    w(3)=min([w1 w2]);
    du(3)=0;
else
    w(3)=0;
    du(3)=0;
end
```

**% Rule 4**

```
if (er>=-1)&(er<=2)&(de>=-6)&(de<=-4)
    w1=(er+1)/3;
    w2=(de+7)/3;
    w(4)=min([w1 w2]);
    du(4)=-2;
elseif (er>=-1)&(er<=2)&(de>=-4)&(de<=-1)
    w1=(er+1)/3;
    w2=- (de+1)/3;
    w(4)=min([w1 w2]);
```

```

du(4)=-2;
elseif (er>=2)&(er<=5)&(de>=-6)&(de<=-4)
    w1=- (er-5)/3;
    w2=(de+7)/3;
    w(4)=min([w1 w2]);
    du(4)=0;
elseif (er>=2)&(er<=5)&(de>=-4)&(de<=-1)
    w1=- (er-5)/3;
    w2=- (de+1)/3;
    w(4)=min([w1 w2]);
    du(4)=-2;
else
    w(4)=0;
    du(4)=0;
end

```

#### **% Rule 5**

```

if (er>=-3)&(er<=0)&(de>=-6)&(de<=-4)
    w1=(er+3)/3;
    w2=(de+7)/3;
    w(5)=min([w1 w2]);
    du(5)=-4;
elseif (er>=-3)&(er<=0)&(de>=-4)&(de<=-1)
    w1=(er+3)/3;
    w2=- (de+1)/3;
    w(5)=min([w1 w2]);
    du(5)=-4;
elseif (er>=0)&(er<=3)&(de>=-6)&(de<=-4)
    w1=- (er-3)/3;
    w2=(de+7)/3;
    w(5)=min([w1 w2]);
    du(5)=-4;
elseif (er>=0)&(er<=3)&(de>=-4)&(de<=-1)
    w1=- (er-3)/3;
    w2=- (de+1)/3;
    w(5)=min([w1 w2]);
    du(5)=-4;
else
    w(5)=0;
    du(5)=0;
end

```

#### **% Rule 6**

```

if (er>=-5)&(er<=-2)&(de>=-5)&(de<=-2)
    w1=(er+5)/3;
    w2=(de+5)/3;
    w(6)=min([w1 w2]);
    du(6)=-4;
elseif (er>=-5)&(er<=-2)&(de>=-2)&(de<=1)
    w1=(er+5)/3;
    w2=- (de-1)/3;
    w(6)=min([w1 w2]);
    du(6)=-4;
elseif (er>=-2)&(er<=1)&(de>=-5)&(de<=-2)
    w1=- (er-1)/3;
    w2=(de+5)/3;
    w(6)=min([w1 w2]);
    du(6)=-4;
elseif (er>=-2)&(er<=1)&(de>=-2)&(de<=1)
    w1=- (er-1)/3;

```

```

w2=-(de-1)/3;
w(6)=min([w1 w2]);
du(6)=-4;
else
w(6)=0;
du(6)=0;
end

```

**% Rule 7**

```

if (er>=-6)&(er<=-4)&(de>=-3)&(de<=0)
w1=(er+7)/3;
w2=(de+3)/3;
w(7)=min([w1 w2]);
du(7)=-4;
elseif (er>=-6)&(er<=-4)&(de>=0)&(de<=3)
w1=(er+7)/3;
w2=-(de-3)/3;
w(7)=min([w1 w2]);
du(7)=-4;
elseif (er>=-4)&(er<=-1)&(de>=-3)&(de<=0)
w1=-(er+1)/3;
w2=(de+3)/3;
w(7)=min([w1 w2]);
du(7)=-4;
elseif (er>=-4)&(er<=-1)&(de>=0)&(de<=3)
w1=-(er+1)/3;
w2=-(de-3)/3;
w(7)=min([w1 w2]);
du(7)=-4;
else
w(7)=0;
du(7)=0;
end

```

**% Rule 8**

```

if (er>=-5)&(er<=-2)&(de>=-1)&(de<=2)
w1=(er+5)/3;
w2=(de+1)/3;
w(8)=min([w1 w2]);
du(8)=0;
elseif (er>=-5)&(er<=-2)&(de>=2)&(de<=5)
w1=(er+5)/3;
w2=-(de-5)/3;
w(8)=min([w1 w2]);
du(8)=0;
elseif (er>=-2)&(er<=1)&(de>=-1)&(de<=2)
w1=-(er-1)/3;
w2=(de+1)/3;
w(8)=min([w1 w2]);
du(8)=0;
elseif (er>=-2)&(er<=1)&(de>=2)&(de<=5)
w1=-(er-1)/3;
w2=-(de-5)/3;
w(8)=min([w1 w2]);
du(8)=0;
else
w(8)=0;
du(8)=0;
end

```

**% Rule 9**

```
if (er>=-3)&(er<=0)&(de>=-3)&(de<=0)
    w1=(er+3)/3;
    w2=(de+3)/3;
    w(9)=min([w1 w2]);
    du(9)=0;
elseif (er>=-3)&(er<=0)&(de>=0)&(de<=3)
    w1=(er+3)/3;
    w2=-(de-3)/3;
    w(9)=min([w1 w2]);
    du(9)=0;
elseif (er>=0)&(er<=3)&(de>=-3)&(de<=0)
    w1=-(er-3)/3;
    w2=(de+3)/3;
    w(9)=min([w1 w2]);
    du(9)=0;
elseif (er>=0)&(er<=3)&(de>=0)&(de<=3)
    w1=-(er-3)/3;
    w2=-(de-3)/3;
    w(9)=min([w1 w2]);
    du(9)=0;
else
    w(9)=0;
    du(9)=0;
end
```

**% Rule 10**

```
if (er>=3)&(er<=6)&(de>=-6)&(de<=-4)
    w1=(er-3)/3;
    w2=(de+7)/3;
    w(10)=min([w1 w2]);
    du(10)=2;
elseif (er>=3)&(er<=6)&(de>=-4)&(de<=-1)
    w1=(er-3)/3;
    w2=-(de+1)/3;
    w(10)=min([w1 w2]);
    du(10)=2;
elseif (er>=6)&(de>=-6)&(de<=-4)
    w(10)=(de+7)/3;
    du(10)=2;
elseif (er>=6)&(de>=-4)&(de<=-1)
    w(10)=-(de+1)/3;
    du(10)=2;
else
    w(10)=0;
    du(10)=0;
end
```

**% Rule 11**

```
if (er>=3)&(er<=6)&(de<=-6)
    w(11)=-(er-3)/3;
    du(11)=0;
elseif (er>=3)&(er<=6)&(de>=-6)&(de<=-3)
    w1=(er-3)/3;
    w2=-(de+3)/3;
    w(11)=min([w1 w2]);
    du(11)=0;
elseif (er>=6)&(de<=-6)
    w(11)=1;
    du(11)=0;
```

```

elseif (er>=6)&(de>=-6)&(de<=-3)
    w(11)=- (de+3)/3;
    du(11)=0;
else
    w(11)=0;
    du(11)=0;
end

```

**% Rule 12**

```

if (er>=1)&(er<=4)&(de<=-6)
    w(12)=(er-1)/3;
    du(12)=-2;
elseif (er>=1)&(er<=4)&(de>=-6)&(de<=-3)
    w1=(er-1)/3;
    w2=- (de+3)/3;
    w(12)=min([w1 w2]);
    du(12)=-2;
elseif (er>=4)&(er<=6)&(de<=-6)
    w(12)=- (er-7)/3;
    du(12)=-2;
elseif (er>=4)&(er<=6)&(de>=-6)&(de<=-3)
    w1=- (er-7)/3;
    w2=- (de+3)/3;
    w(12)=min([w1 w2]);
    du(12)=-2;
else
    w(12)=0;
    du(12)=0;
end

```

**% Rule 13**

```

if (er>=-1)&(er<=2)&(de<=-6)
    w(13)=(er+1)/3;
    du(13)=-4;
elseif (er>=-1)&(er<=2)&(de>=-6)&(de<=-3)
    w1=(er+1)/3;
    w2=- (de+3)/3;
    w(13)=min([w1 w2]);
    du(13)=-4;
elseif (er>=2)&(er<=5)&(de<=-6)
    w(13)=- (er-5)/3;
    du(13)=-4;
elseif (er>=2)&(er<=5)&(de>=-6)&(de<=-3)
    w1=- (er-5)/3;
    w2=- (de+3)/3;
    w(13)=min([w1 w2]);
    du(13)=-4;
else
    w(13)=0;
    du(13)=0;
end

```

**% Rule 14**

```

if (er>=-3)&(er<=0)&(de<=-6)
    w(14)=(er+3)/3;
    du(14)=-6;
elseif (er>=-3)&(er<=0)&(de>=-6)&(de<=-3)
    w1=(er+3)/3;
    w2=- (de+3)/3;
    w(14)=min([w1 w2]);

```

```

du(14)=-6;
elseif (er>=0)&(er<=3)&(de<=-6)
    w(14)=-(-er-3)/3;
    du(14)=-6;
elseif (er>=0)&(er<=3)&(de>=-6)&(de<=-3)
    w1=-(-er-3)/3;
    w2=-(-de+3)/3;
    w(14)=min([w1 w2]);
    du(14)=-6;
else
    w(14)=0;
    du(14)=0;
end

```

**% Rule 15**

```

if (er>=-5)&(er<=-2)&(de<=-6)
    w(15)=(er+5)/3;
    du(15)=-6;
elseif (er>=-5)&(er<=-2)&(de>=-6)&(de<=-3)
    w1=(er+5)/3;
    w2=-(-de+3)/3;
    w(15)=min([w1 w2]);
    du(15)=-6;
elseif (er>=-2)&(er<=1)&(de<=-6)
    w(15)=-(-er-1)/3;
    du(15)=-6;
elseif (er>=-2)&(er<=1)&(de>=-6)&(de<=-3)
    w1=-(-er-1)/3;
    w2=-(-de+3)/3;
    w(15)=min([w1 w2]);
    du(15)=-6;
else
    w(15)=0;
    du(15)=0;
end

```

**% Rule 16**

```

if (er>=-6)&(er<=-4)&(de>=-6)&(de<=-4)
    w1=(er+7)/3;
    w2=(de+7)/3;
    w(16)=min([w1 w2]);
    du(16)=-6;
elseif (er>=-6)&(er<=-4)&(de>=-4)&(de<=-1)
    w1=(er+7)/3;
    w2=-(-de+1)/3;
    w(16)=min([w1 w2]);
    du(16)=-6;
elseif (er>=-4)&(er<=-1)&(de>=-6)&(de<=-4)
    w1=-(-er+1)/3;
    w2=(de+7)/3;
    w(16)=min([w1 w2]);
    du(16)=-6;
elseif (er>=-4)&(er<=-1)&(de>=-4)&(de<=-1)
    w1=-(-er+1)/3;
    w2=-(-de+1)/3;
    w(16)=min([w1 w2]);
    du(16)=-6;
else
    w(16)=0;
    du(16)=0;
end

```

end

**% Rule 17**

```
if (er<=-6)&(de>=-5)&(de<=-2)
    w(17)=(de+5)/3;
    du(17)=-6;
elseif (er<=-6)&(de>=-2)&(de<=1)
    w(17)=-(de-1)/3;
    du(17)=-6;
elseif (er>=-6)&(er<=-3)&(de>=-5)&(de<=-2)
    w1=-(er+3)/3;
    w2=(de+5)/3;
    w(17)=min([w1 w2]);
    du(17)=-6;
elseif (er>=-6)&(er<=-3)&(de>=-2)&(de<=1)
    w1=-(er+3)/3;
    w2=-(de-1)/3;
    w(17)=min([w1 w2]);
    du(17)=-6;
else
    w(17)=0;
    du(17)=0;
end
```

**% Rule 18**

```
if (er<=-6)&(de>=-3)&(de<=0)
    w(18)=(de+3)/3;
    du(18)=-6;
elseif (er<=-6)&(de>=0)&(de<=3)
    w(18)=-(de-3)/3;
    du(18)=-6;
elseif (er>=-6)&(er<=-3)&(de>=-3)&(de<=0)
    w1=-(er+3)/3;
    w2=(de+3)/3;
    w(18)=min([w1 w2]);
    du(18)=-6;
elseif (er>=-6)&(er<=-3)&(de>=0)&(de<=3)
    w1=-(er+3)/3;
    w2=-(de-3)/3;
    w(18)=min([w1 w2]);
    du(18)=-6;
else
    w(18)=0;
    du(18)=0;
end
```

**% Rule 19**

```
if (er>=-6)&(er<=-4)&(de>=-1)&(de<=2)
    w1=(er+7)/3;
    w2=(de+1)/3;
    w(19)=min([w1 w2]);
    du(19)=-2;
elseif (er>=-6)&(er<=-4)&(de>=2)&(de<=5)
    w1=(er+7)/3;
    w2=-(de-5)/3;
    w(19)=min([w1 w2]);
    du(19)=-2;
elseif (er>=-4)&(er<=-1)&(de>=-1)&(de<=2)
    w1=-(er+3)/3;
    w2=(de+1)/3;
```



```

    w(19)=min([w1 w2]);
    du(19)=-2;
elseif (er>=-4)&(er<=-1)&(de>=2)&(de<=5)
    w1=-(er+1)/3;
    w2=-(de-5)/3;
    w(19)=min([w1 w2]);
    du(19)=-1;
else
    w(19)=0;
    du(19)=0;
end

```

#### **% Rule 20**

```

if (er>=-5)&(er<=-2)&(de>=1)&(de<=4)
    w1=(er+5)/3;
    w2=(de-1)/3;
    w(20)=min([w1 w2]);
    du(20)=2;
elseif (er>=-5)&(er<=-2)&(de>=4)&(de<=6)
    w1=(er+5)/3;
    w2=-(de-7)/3;
    w(20)=min([w1 w2]);
    du(20)=2;
elseif (er>=-2)&(er<=1)&(de>=1)&(de<=4)
    w1=-(er-1)/3;
    w2=(de-1)/3;
    w(20)=min([w1 w2]);
    du(20)=2;
elseif (er>=-2)&(er<=1)&(de>=4)&(de<=6)
    w1=-(er-1)/3;
    w2=-(de-7)/3;
    w(20)=min([w1 w2]);
    du(20)=2;
else
    w(20)=0;
    du(20)=0;
end

```

#### **% Rule 21**

```

if (er>=-3)&(er<=0)&(de>=-1)&(de<=2)
    w1=(er+3)/3;
    w2=(de+1)/3;
    w(21)=min([w1 w2]);
    du(21)=2;
elseif (er>=-3)&(er<=0)&(de>=2)&(de<=5)
    w1=(er+3)/3;
    w2=-(de-5)/3;
    w(21)=min([w1 w2]);
    du(21)=2;
elseif (er>=0)&(er<=3)&(de>=-1)&(de<=2)
    w1=-(er-3)/3;
    w2=(de+1)/3;
    w(21)=min([w1 w2]);
    du(21)=2;
elseif (er>=0)&(er<=3)&(de>=2)&(de<=5)
    w1=-(er-3)/3;
    w2=-(de-5)/3;
    w(21)=min([w1 w2]);
    du(21)=2;
else

```

```
w(21)=0;
du(21)=0;
end
```

**% Rule 22**

```
if (er>=-1)&(er<=2)&(de>=-3)&(de<=0)
    w1=(er+1)/3;
    w2=(de+3)/3;
    w(22)=min([w1 w2]);
    du(22)=2;
elseif (er>=-1)&(er<=2)&(de>=0)&(de<=3)
    w1=(er+1)/3;
    w2=- (de-3)/3;
    w(22)=min([w1 w2]);
    du(22)=2;
elseif (er>=2)&(er<=5)&(de>=-3)&(de<=0)
    w1=- (er-5)/3;
    w2=(de+3)/3;
    w(22)=min([w1 w2]);
    du(22)=2;
elseif (er>=2)&(er<=5)&(de>=0)&(de<=3)
    w1=- (er-5)/3;
    w2=- (de-3)/3;
    w(22)=min([w1 w2]);
    du(22)=2;
else
    w(22)=0;
    du(22)=0;
end
```

**% Rule 23**

```
if (er>=-1)&(er<=2)&(de>=-5)&(de<=-2)
    w1=(er+1)/3;
    w2=(de+5)/3;
    w(23)=min([w1 w2]);
    du(23)=0;
elseif (er>=-1)&(er<=2)&(de>=-2)&(de<=1)
    w1=(er+1)/3;
    w2=- (de-1)/3;
    w(23)=min([w1 w2]);
    du(23)=0;
elseif (er>=2)&(er<=5)&(de>=-5)&(de<=-2)
    w1=- (er-5)/3;
    w2=(de+5)/3;
    w(23)=min([w1 w2]);
    du(23)=0;
elseif (er>=2)&(er<=5)&(de>=-2)&(de<=1)
    w1=- (er-5)/3;
    w2=- (de-1)/3;
    w(23)=min([w1 w2]);
    du(23)=0;
else
    w(23)=0;
    du(23)=0;
end
```

**% Rule 24**

```
if (er>=-5)&(er<=-2)&(de>=-3)&(de<=0)
    w1=(er+5)/3;
    w2=(de+3)/3;
```

```

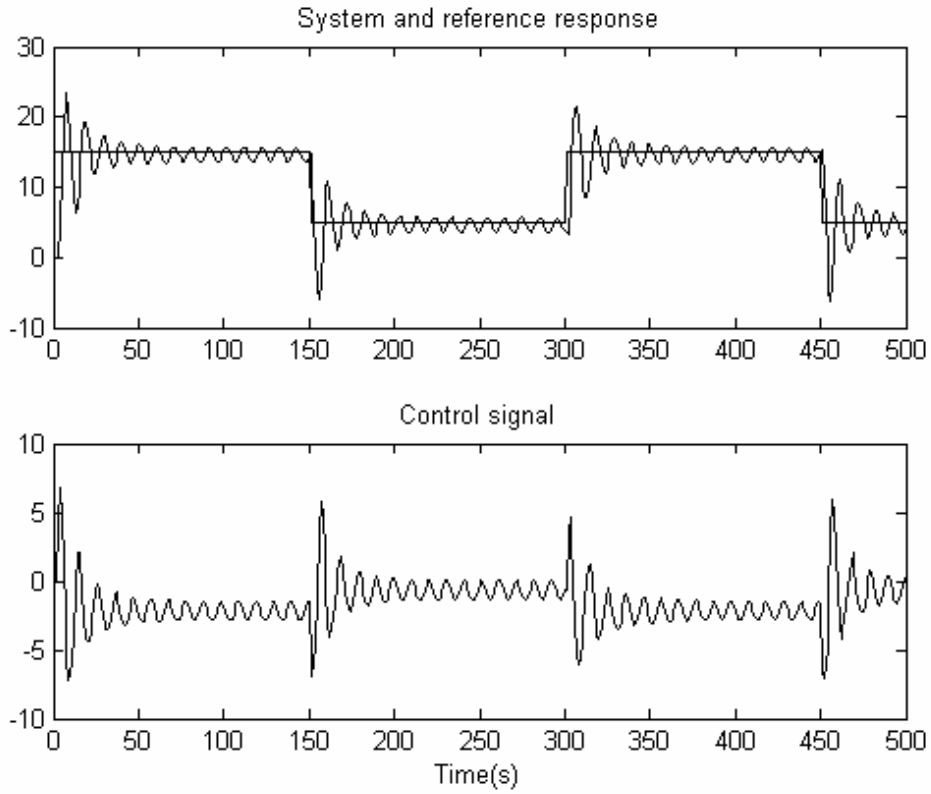
w(24)=min([w1 w2]);
du(24)=-2;
elseif (er>=-5)&(er<=-2)&(de>=0)&(de<=3)
w1=(er+5)/3;
w2=-(de-3)/3;
w(24)=min([w1 w2]);
du(24)=-2;
elseif (er>=-2)&(er<=1)&(de>=-3)&(de<=0)
w1=-(er-1)/3;
w2=(de+3)/3;
w(24)=min([w1 w2]);
du(24)=-2;
elseif (er>=-2)&(er<=1)&(de>=0)&(de<=3)
w1=-(er-1)/3;
w2=-(de-3)/3;
w(24)=min([w1 w2]);
du(24)=-2;
else
w(24)=0;
du(24)=0;
end

% Defuzzification
a=sum(w);
if a==0
Deltau=0;
else
Deltau = ( w*du)/(sum(w));
end
% The applied Control signal
u(k)=u(k-1)+Kout*Deltau;
end

subplot(211),plot(t,yref,t,y)
title('System and reference response')
subplot(212),plot(t,u),xlabel('Time(s)')
title('Control signal')

```

- Responses linear system (Unstable):



- Nonlinear system response:

