Parameters:

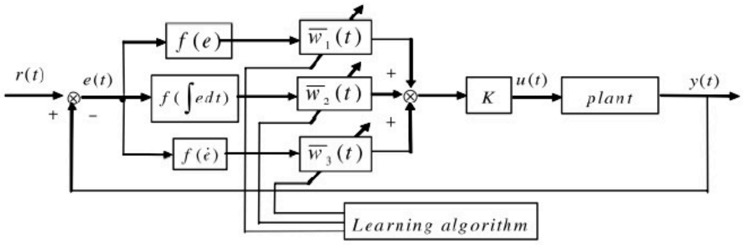


Fig. 1 Neuron based Nonlinear PID Controller

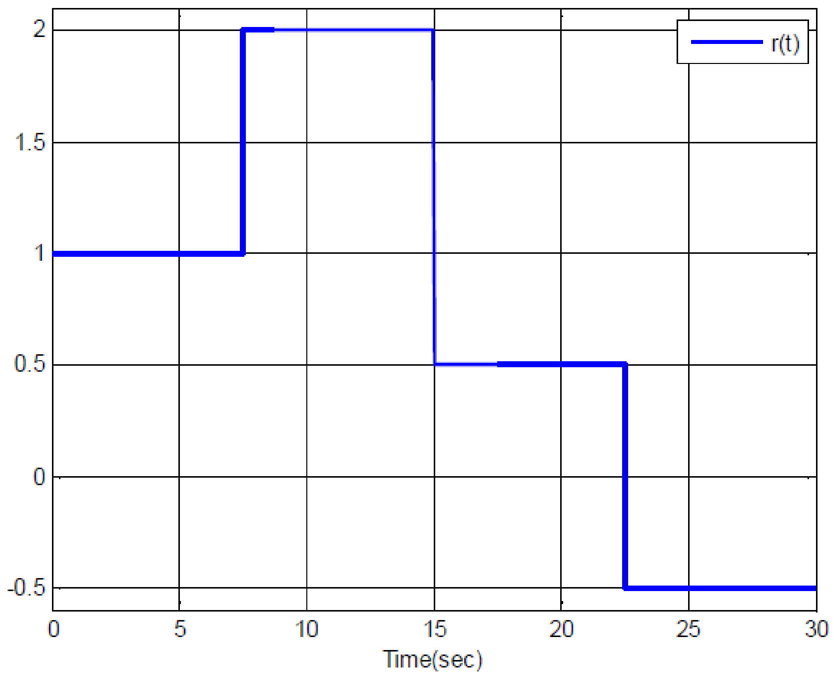
The neuron based nonlinear PID Controller in figure is going to beused to control paper making process. The dynamic characteristics of the plant is as follows:

$$G(z) = \frac{0.4484}{z\,(z - 0.7788)}, when\ 100\ g/m^2\ paper\ is\ made$$

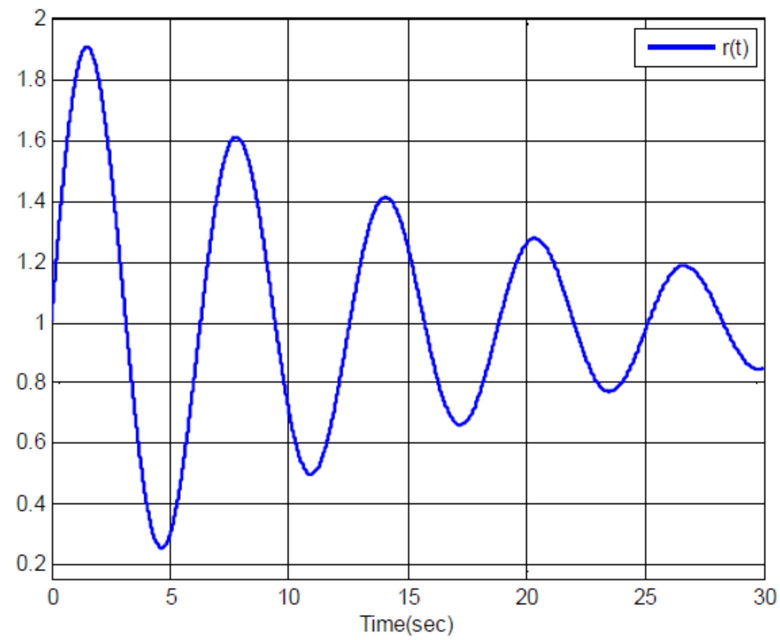
The controller parameters are selected as follows:

$K = 1.1$, $\eta_1 = 15$, $\eta_2 = 1$, $\eta_3 = 10$
$\alpha_P = 1$, $\alpha_I = 0.5$, $\alpha_D = 0.5$,
$\delta_P = 0.1$, $\delta_I = 0.4$, $\delta_D = 0.3$

First Ref Signal:



Second Ref Signal:



The Non-linear PID Controller:

Control Signal:

$$u(t) = K_P(t) f(e(t), \alpha_P, \delta_P) + K_I(t) f(\int e(t), \alpha_I, \delta_I) + K_D(t) f(\dot{e}(t), \alpha_D, \delta_D)$$

$f(.)$ is the non-linear function defined as :

$$f(x, \alpha, \delta) = \begin{cases} sign(x)|x|^{a} & , when \ |x| > \delta \\ \delta^{a-1} x & , when \ |x| \le \delta \end{cases}$$

Usually $0 < a \le 1$.

The Neuron Controller:

The neuron model free control method is proposed as follows

$$u(t) = \frac{K \sum_{i=1}^{n} w_i(t) x_i(t)}{\sum_{i=1}^{n} w_i(t)}$$

$$w_i(t+1) = w_i(t) + de(t)u(t)x_i(t)$$

where $u(t)$, $y(t)$ are the input and the output of the system respectively, and $u(t)$ is the control signal produced by the neuron.

The neuron based Nonlinear PID Controller:

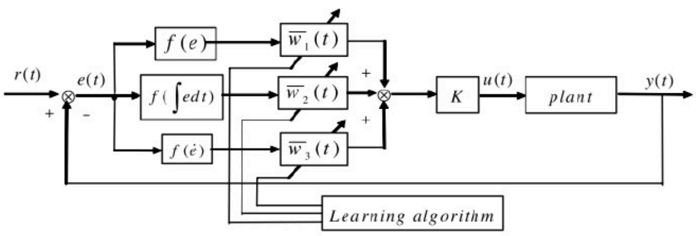


Fig. 2. The neuron based nonlinear PID control system

The neuron based nonlinear PID Controller is as in fig. 2. In this controlsystem, the neuron based nonlinear PID controller is constructed by selecting the neuron inputs, and the control action of the nonlinear PID controller are determined by modifying the neuron weights on-line. The neuron based nonlinear PID controller produce the controller signal in model-free way. For detailed information, [3] has been referred.

Control Algorithm:

Step 0: Set $n = 1$

Step 1: Calculate tracking error $e_{tr}(n) = r(n) - y(n)$

Step 2: Calculate inputs of the PID Controller

$$
\begin{aligned}
P(n) &= e_{tr}(n) \\
I(n) &= I(n-1) + e_{tr}(n) \\
D(n) &= e_{tr}(n) - e_{tr}(n-1)
\end{aligned}
$$

Step 3: Calculate outputs of $f(.)$ nonlinear function

$$
\begin{aligned}
x_P(n) &= f(e_{tr}(n), \alpha_P, \delta_P) \\
x_I(n) &= f(\int e_{tr}(n)\,dn, \alpha_I, \delta_I) \\
x_D(n) &= f(\dot{e}_{tr}(n), \alpha_D, \delta_D)
\end{aligned}
$$

Step 4: Calculate control signal

$$
\begin{aligned}
u(n) &= K\frac{w_1(n)x_P(n) + w_2(n)x_I(n) + w_3(n)x_D(n)}{w_1(n) + w_2(n) + w_3(n)} \\
&= K_p(n)x_P(n) + K_I(n)x_I(n) + K_D(n)x_D(n)
\end{aligned}
$$

Step 5: Apply control signal to the plant and obtain output of the system

$y(n+1) = ?$

Step 6: Update controller parameters

$$
\begin{aligned}
w_1(n+1) &= w_1(n) + d_1 e_{tr}(n)u(n)x_P(n) \\
w_2(n+1) &= w_2(n) + d_2 e_{tr}(n)u(n)x_I(n) \\
w_3(n+1) &= w_3(n) + d_3 e_{tr}(n)u(n)x_D(n)
\end{aligned}
$$

Step 7: $n \leftarrow n+1$ and go to **Step 1.**