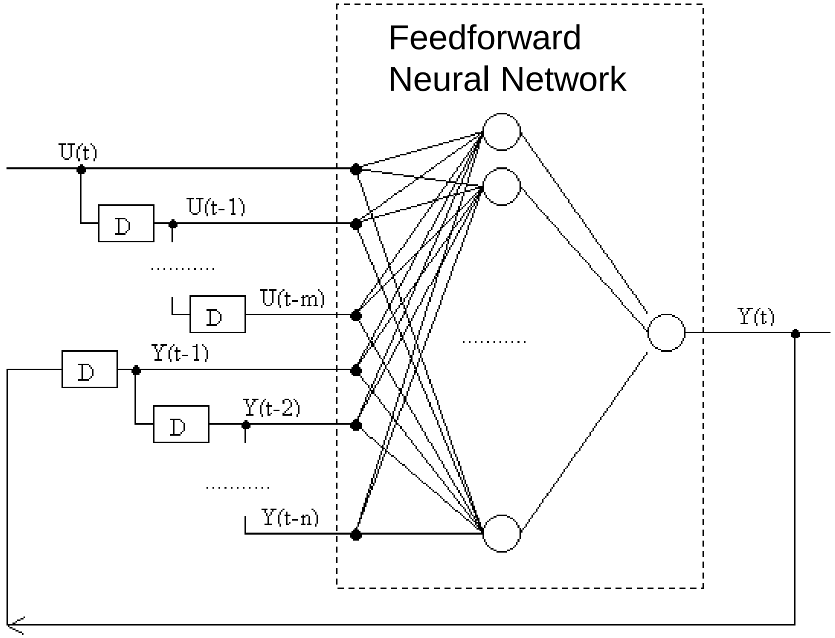
Lab

Neural Networks based control of nonlinear systems

Identification of dynamic systems with Artificial Neural Networks

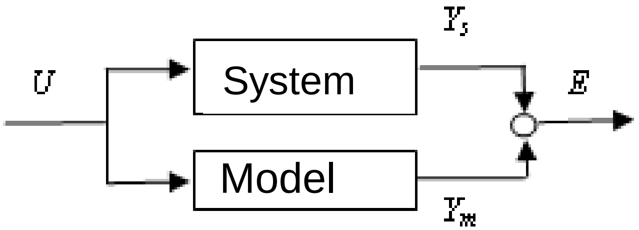
Dynamic/ feedback network:



$$y(t) = F_2 \cdot (W_2 \cdot (F_1 \cdot (W_1 \cdot \begin{bmatrix} u(t) \\ \vdots \\ u(t-m) \\ y(t-1) \\ \vdots \\ y(t-n) \end{bmatrix} + \Theta_1) + \Theta_2) =$$

$$= f_{nn}(u(t), \ldots, u(t-m), y(t-1), \ldots, y(t-n))$$

Identification with Artificial Neural Networks



$$E = Y_s - Y_m$$

$$E \to 0$$

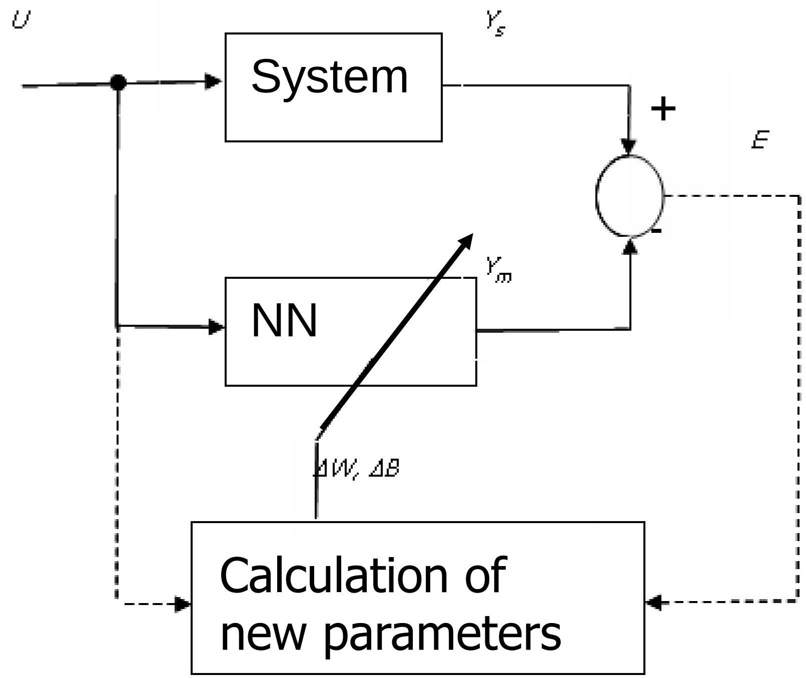
U is theinput of the system and the model

Y_s is the output of the system

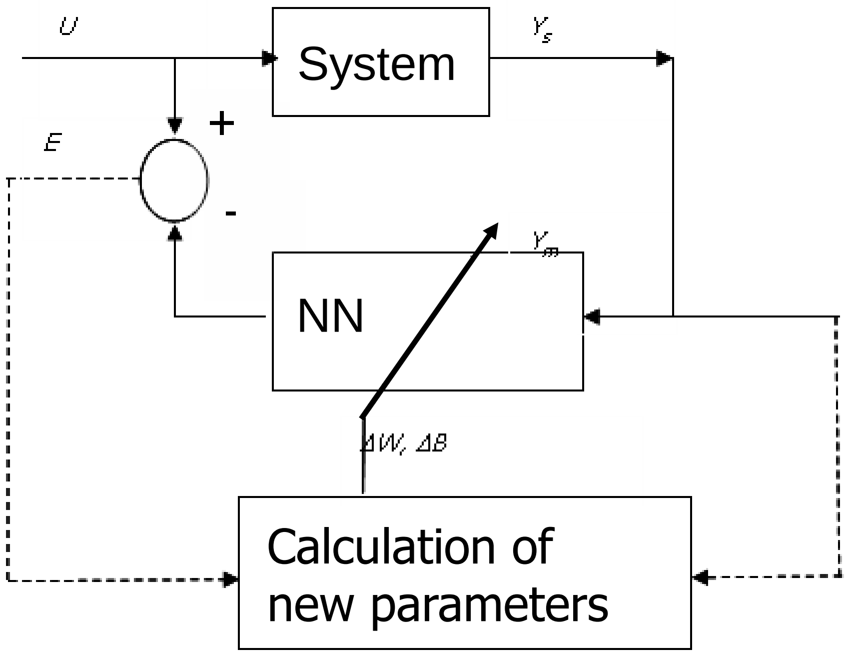
Y_m is the output of the model

1918
TALLINNA
TEHNIKAÜLIKOOL

Identification with Artificial Neural Networks



Inverse model



1918 TALLINNA TEHNIKAÜLIKOOL

Inverse model

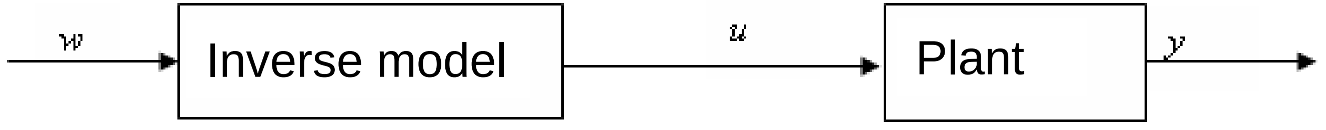
$$f^{-1}: Y(t) \rightarrow U(t-1)$$

$$U(t-1) = f^{-1}(Y(t), \ldots, Y(t-q), U(t-2), \ldots, U(t-r))$$

Consider a system: $y(t) = f^{-1}(y(t-1), y(t-2), u(t-1), u(t-2))$

$$u(t-1) = f^{-1}(y(t), y(t-1), y(t-2)u(t-2))$$

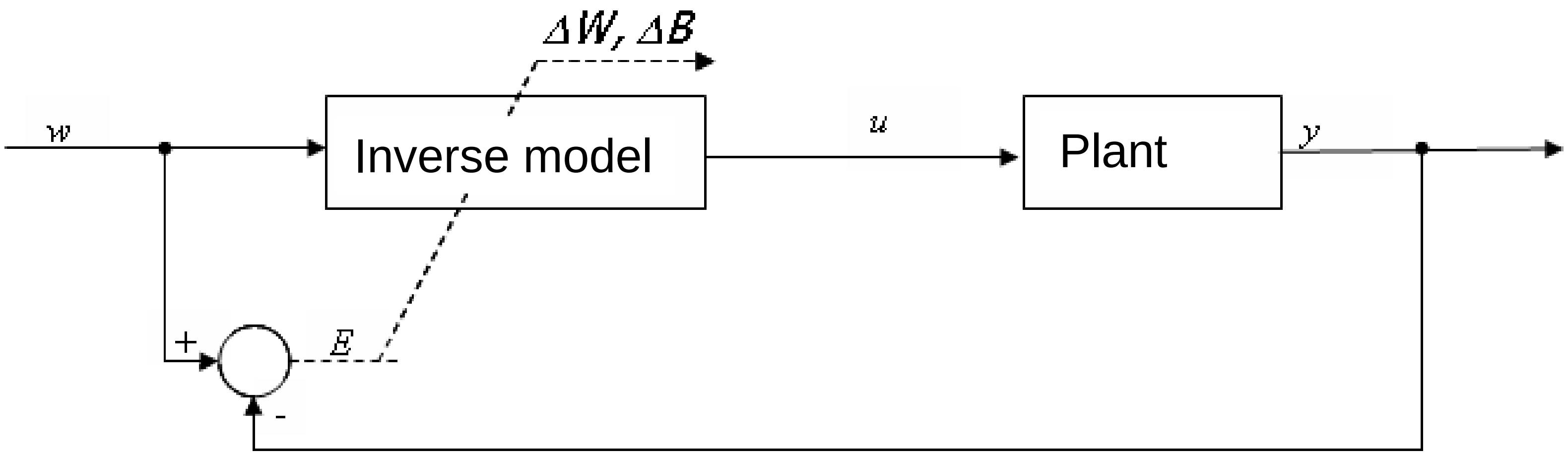
Inverse model based control



$$u(t-1) = f^{-1}(y(t), y(t-1), y(t-2), u(t-2))$$

Here $y(t) = w(t)$

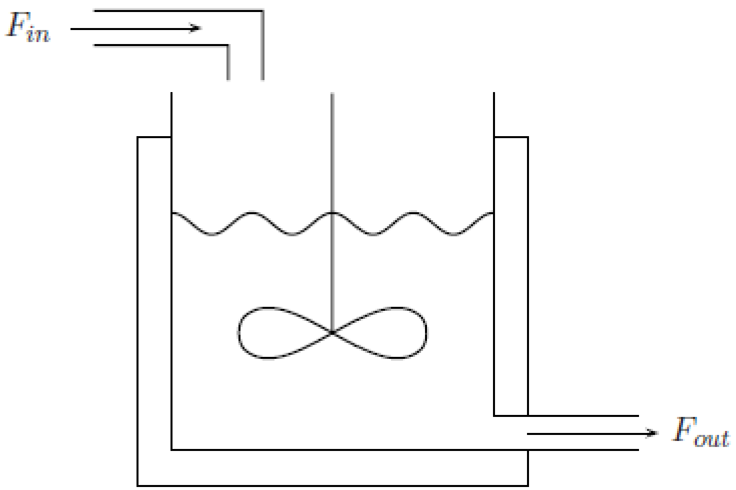
Inverse model based adaptive control



$$E \to 0$$

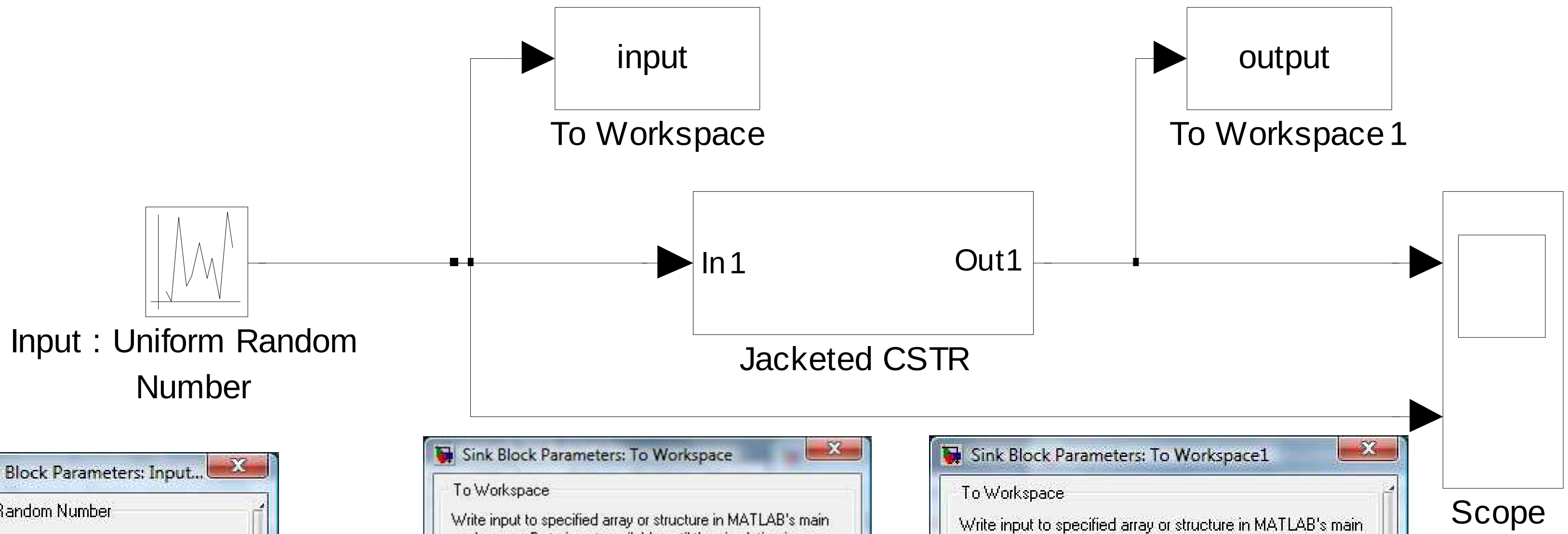
Example: Jacketed CSTR (Continuous Stirred Tank Reactor)

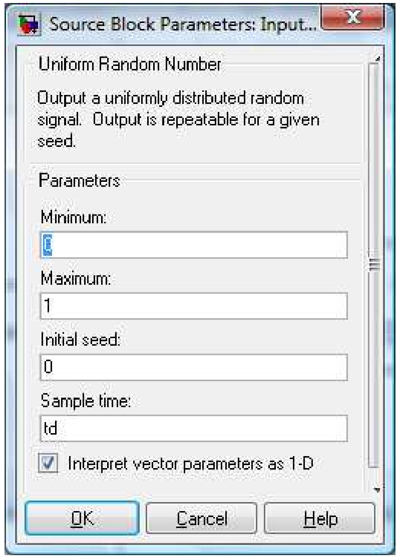
Input-Output equation:

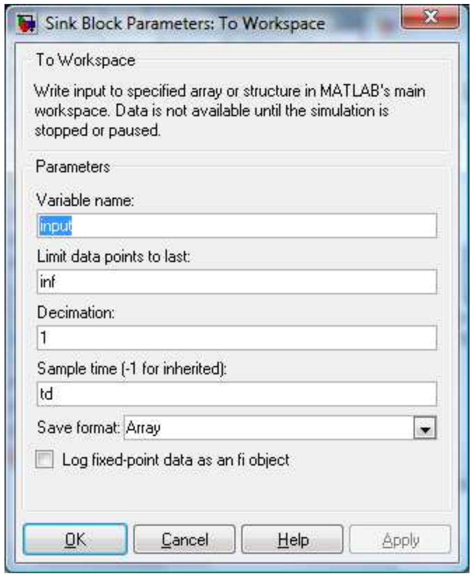


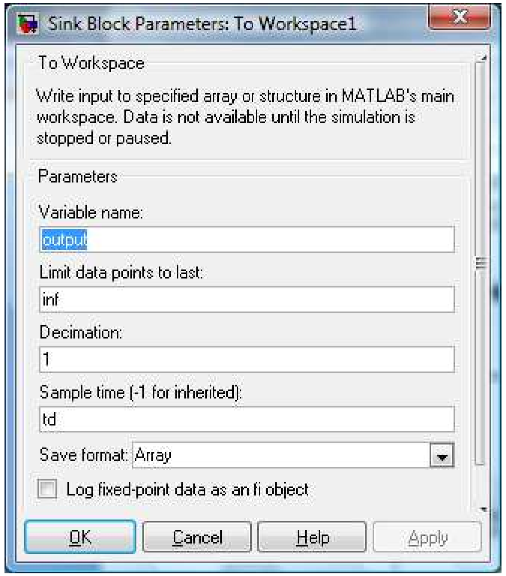
$$y(t+2) = 0.7653y(t+1) - 0.231y(t) +$$
$$+ 0.4801u(t+1) - 0.6407y^2(t+1) +$$
$$+ 1.014y(t)y(t+1) - 0.3921y^2(t+1) +$$
$$+ 0.592y(t+1)u(t+1) - 0.5611y(t)u(t+1)$$

Collecting input-output data









Training of inverse model

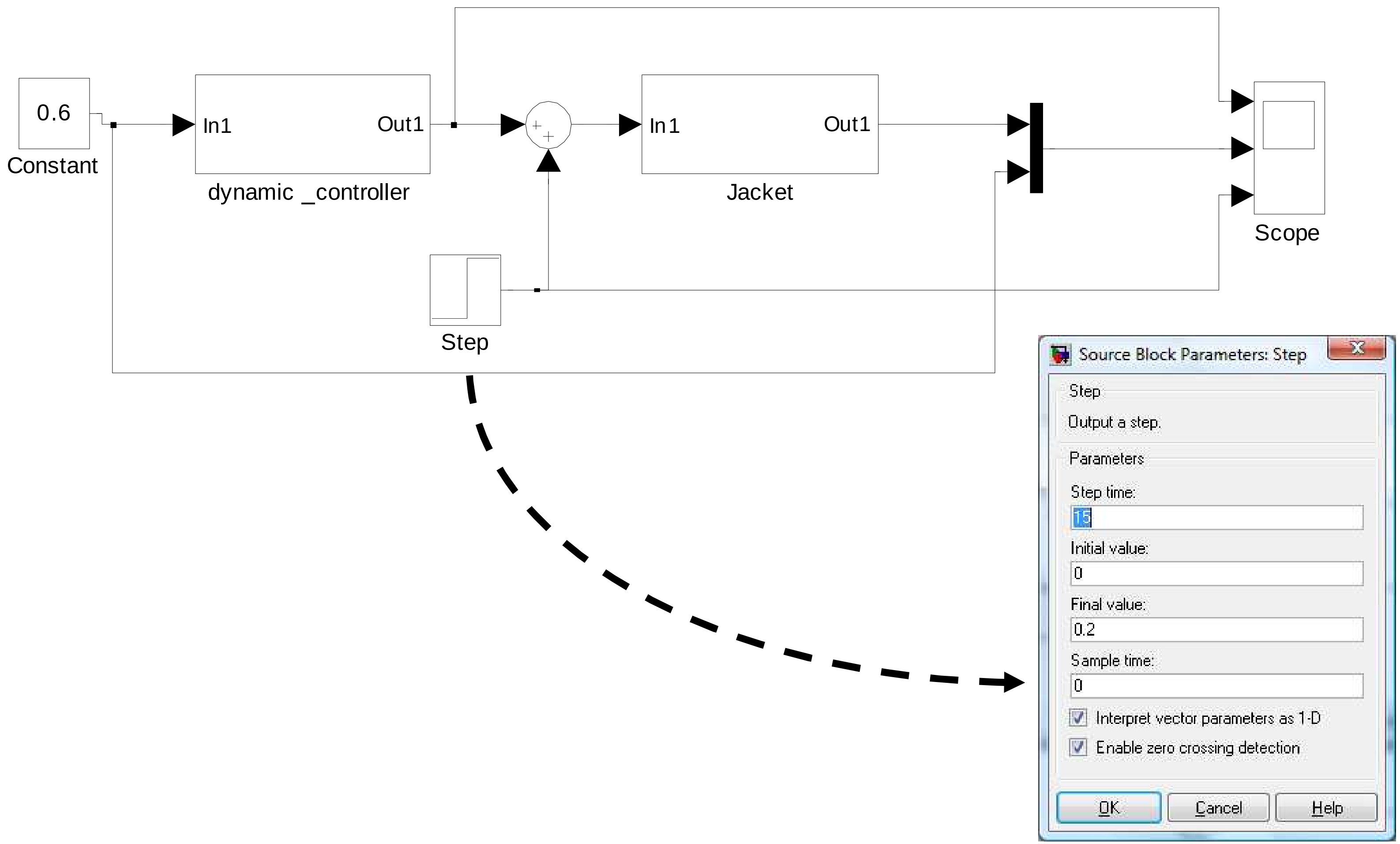
```
td=1
N=size(output,1)
P=[output(3:N)';output(2:N-1)';output(1:N-2)']
T=input(2:N-1)'
global net_c

net_c=newff([0 1; 0 1; 0 1],[5 1],{'tansig','purelin'})
net_c.trainParam.show=1;
net_c.trainFcn='traingd';
net_c.trainParam.epochs=3000;
net_c=train(net_c,P,T)
```

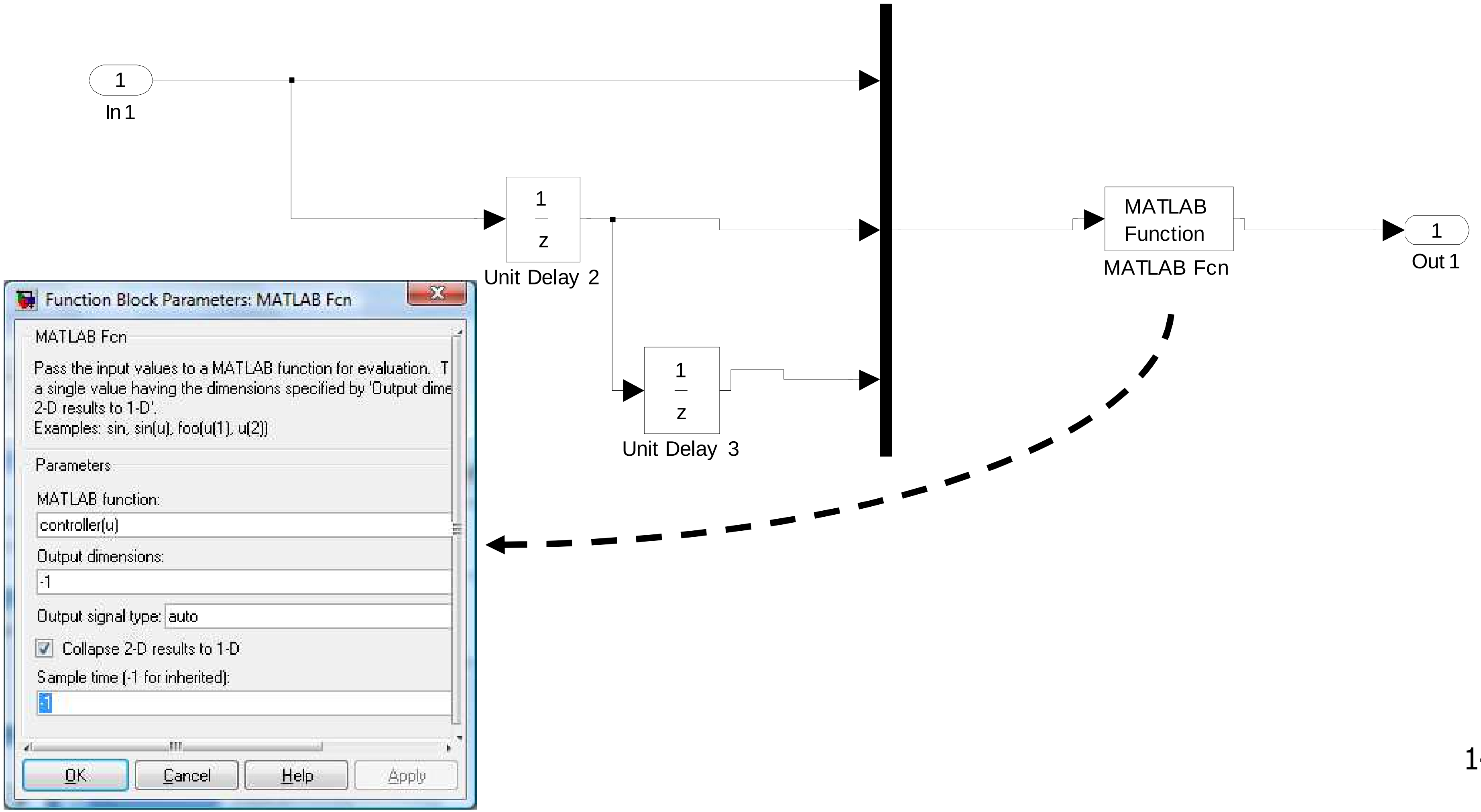
Implementation of the controller in MATLAB (m-file controller.m)

```
function control=controller(u)
global net_c
control=sim(net_c,u);
```

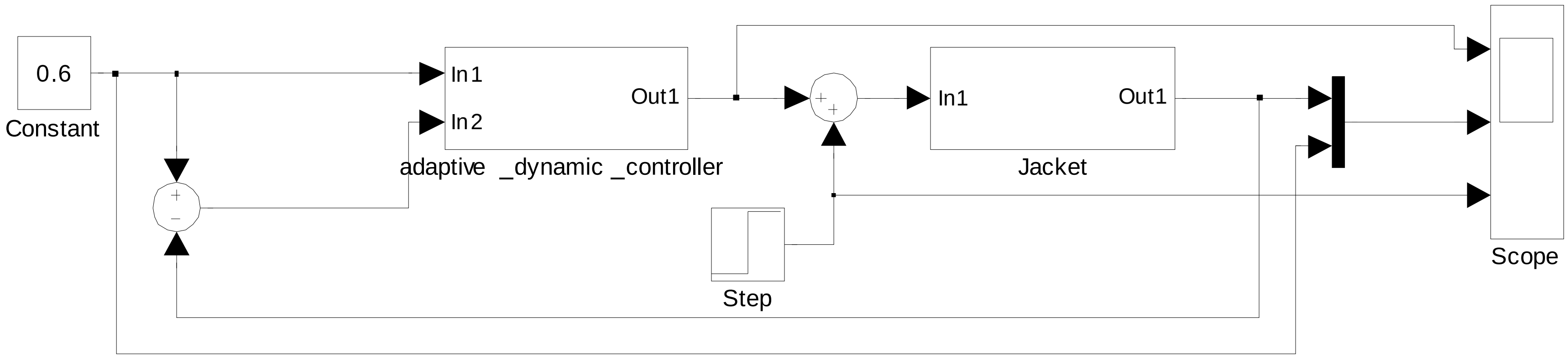
Control scheme



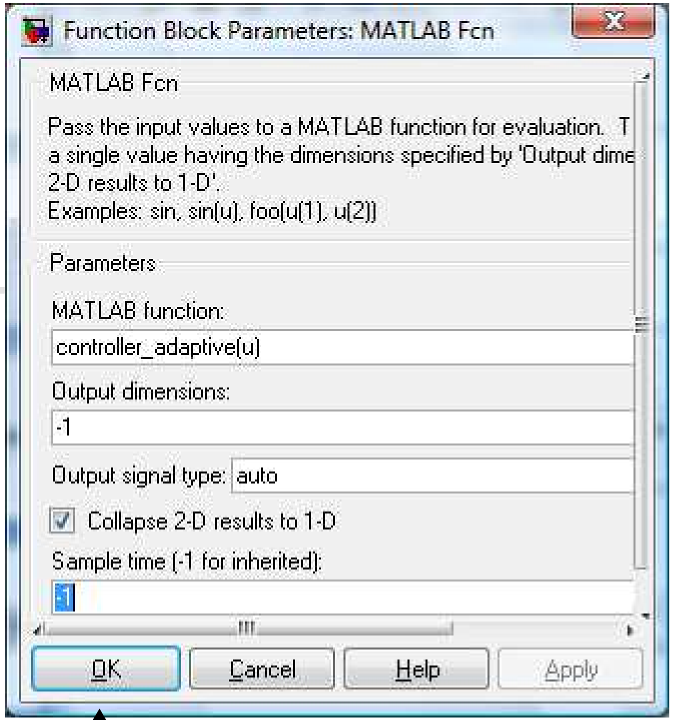
“dynamic_controller” block

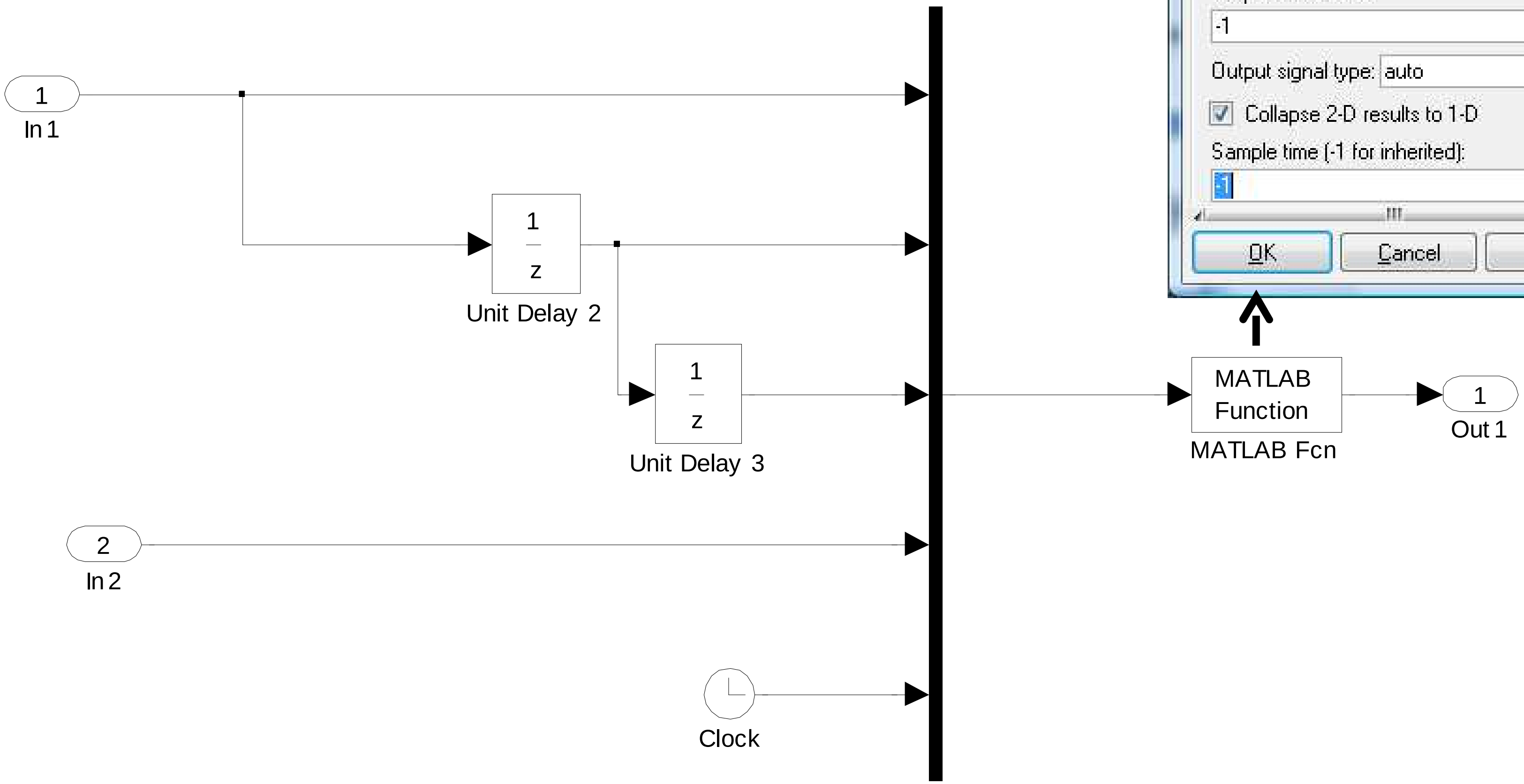


Adaptive control scheme



“adaptive_dynamic_controller” block





Adaptive controller = function "controller_adaptive" (m-file controller_adaptive.m)

```
function control=controller_adaptive(u)
global net_c
inp=u(1:3);
error=u(4);
time=u(5);
control=sim(net_c,inp);
if time>10
net_c=adapt(net_c,inp,control+error);
end
```