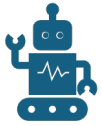






INTERNATIONAL HELLENIC UNIVERSITY

POLYTECHNIC SCHOOL

DEPARTMENT OF COMPUTER, INFORMATICS AND TELECOMMUNICATIONS ENGINEERING

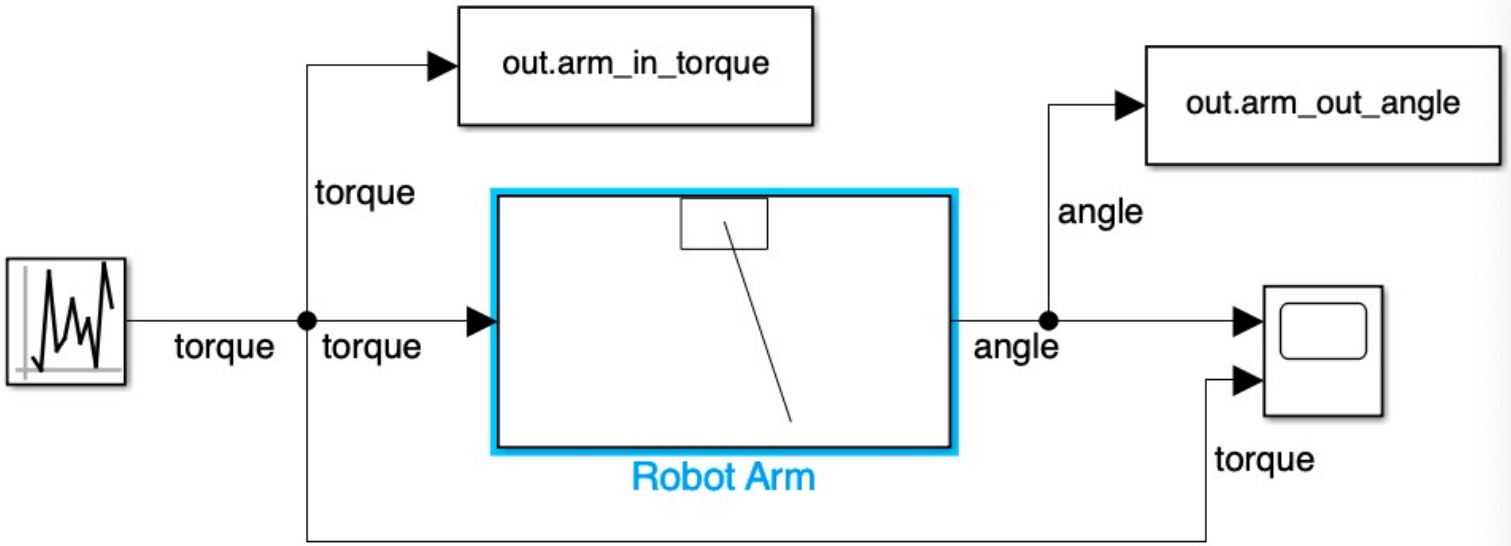
M.Sc. in ROBOTICS

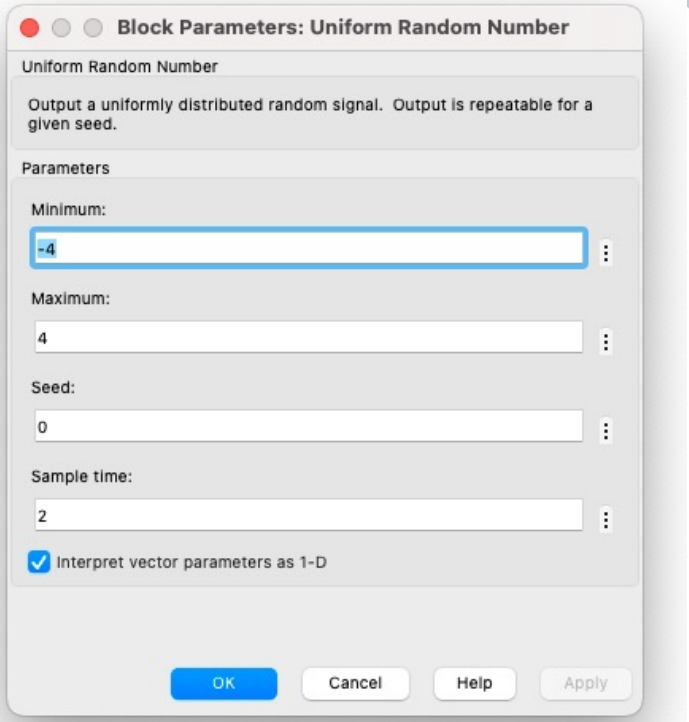
P202 – MACHINE INTELLIGENCE

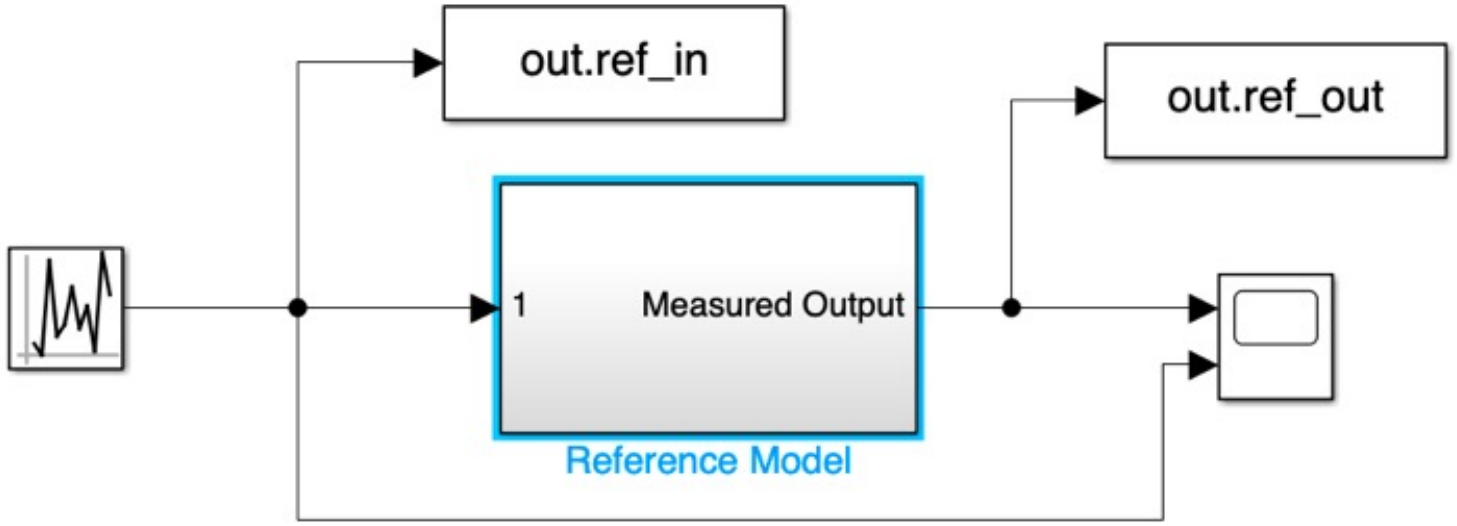
NNArm

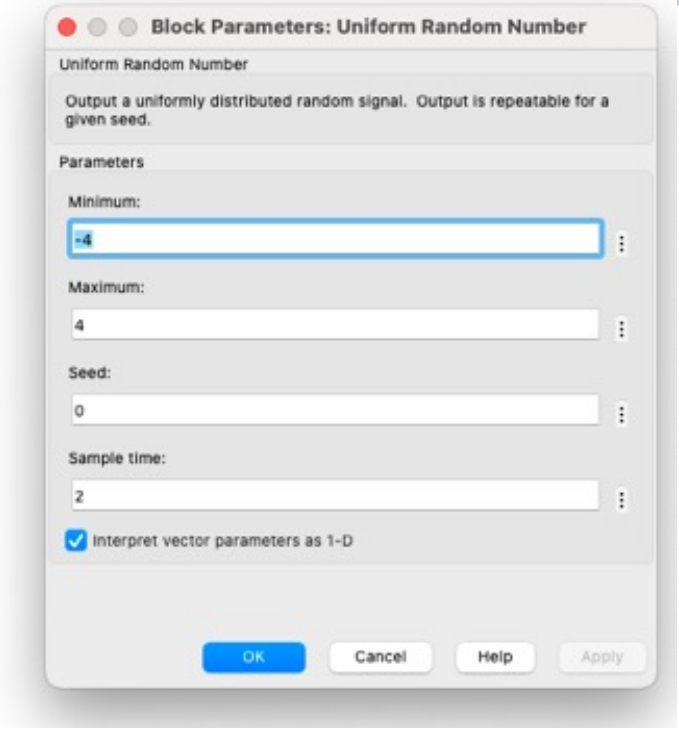
NNArm is a MATLAB/Simulink-based project for controlling a robotic arm using advanced neural network control techniques

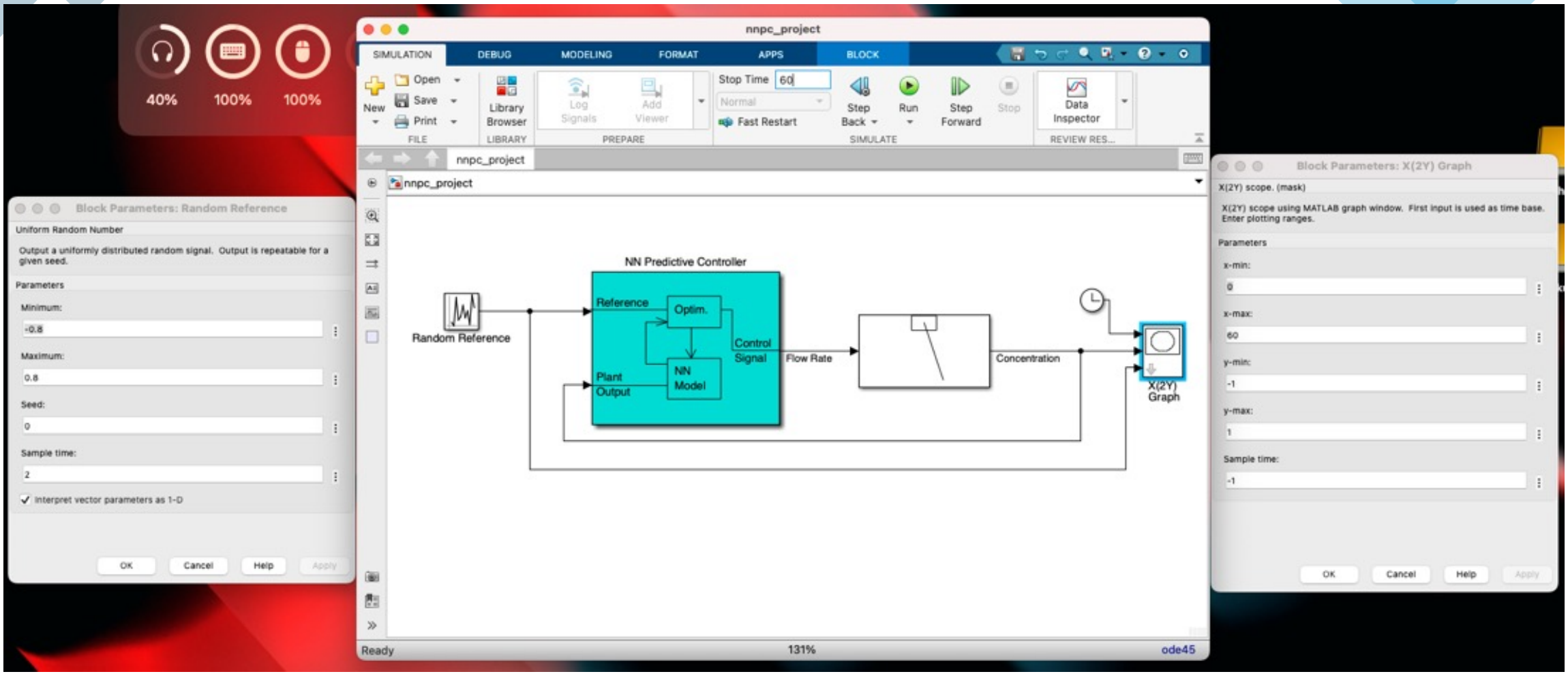
Semester Project on Neural Networks of the Postgraduate Student
Kostelidis Iordanis


out.arm_in_torque
torque
out.arm_out_angle
angle
torque
torque
angle
torque
Robot Arm

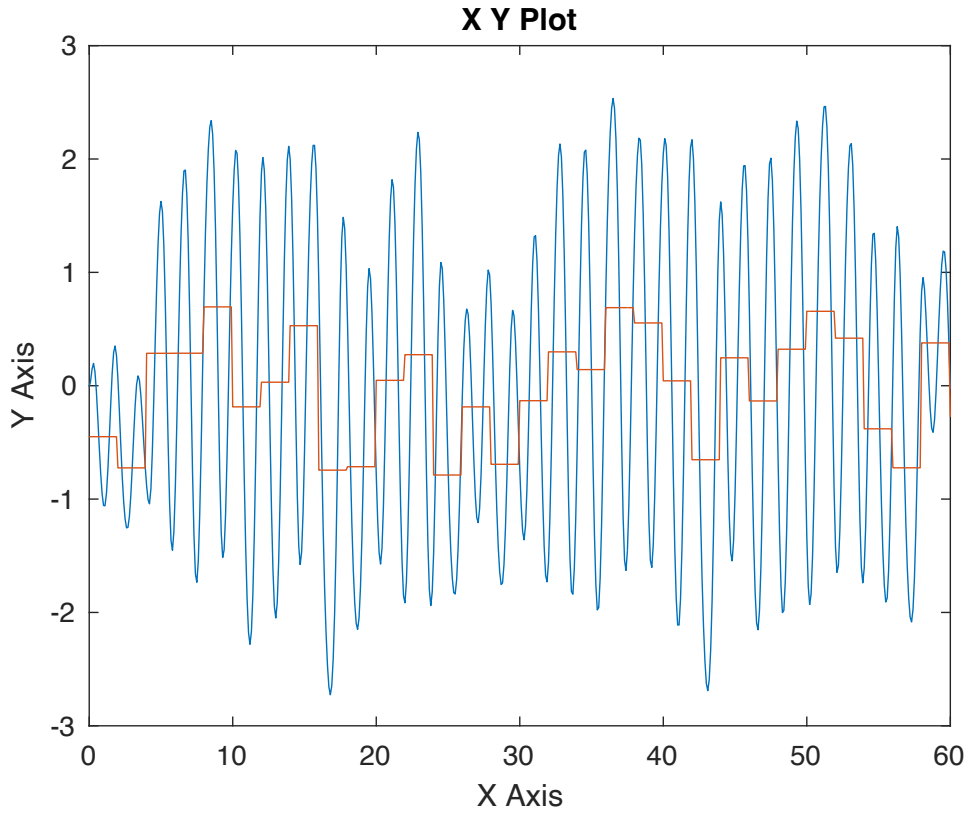

Block Parameters: Uniform Random Number
Uniform Random Number
Output a uniformly distributed random signal. Output is repeatable for a given seed.
Parameters
Minimum:
-4
Maximum:
4
Seed:
0
Sample time:
2
Interpret vector parameters as 1-D
OK
Cancel
Help
Apply

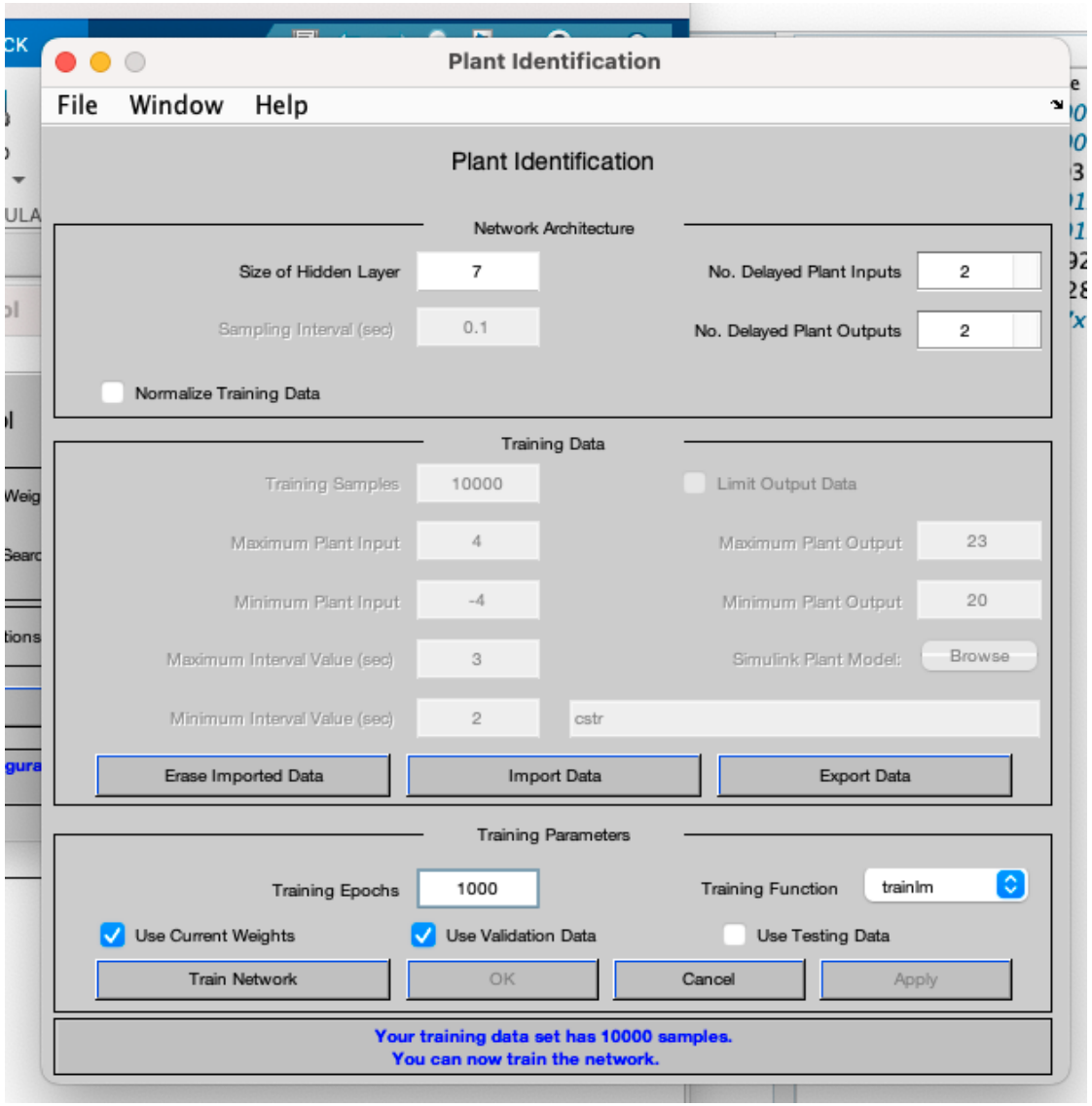

out.ref_in
out.ref_out
1
Measured Output
Reference Model

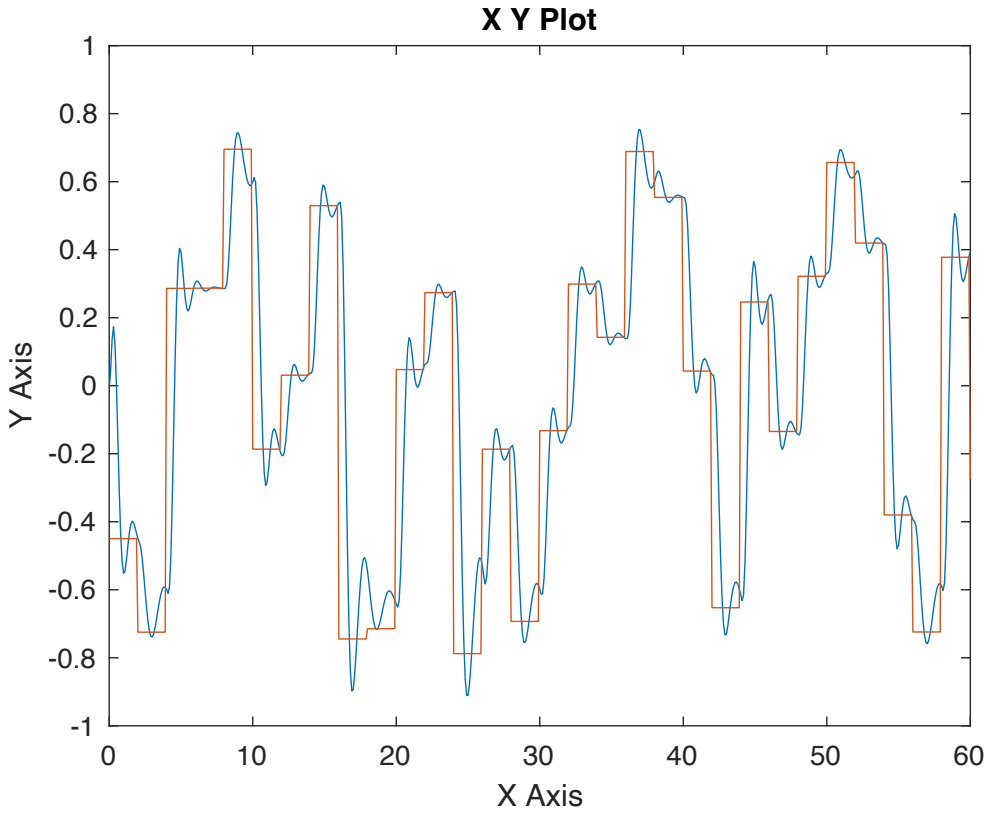

Block Parameters: Uniform Random Number
Uniform Random Number
Output a uniformly distributed random signal. Output is repeatable for a given seed.
Parameters
Minimum:
-4
Maximum:
4
Seed:
0
Sample time:
2
Interpret vector parameters as 1-D
OK
Cancel
Help
Apply

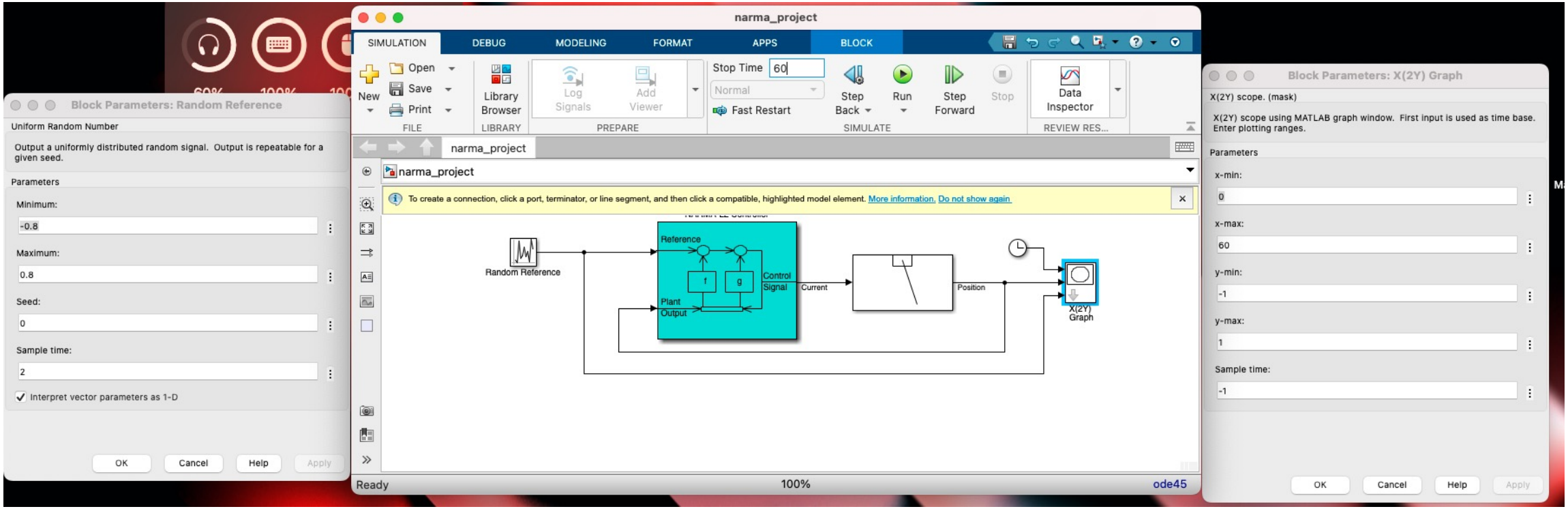

40%
100%
100%
nnpc_project
SIMULATION
DEBUG
MODELING
FORMAT
APPS
BLOCK
New
Open
Save
Print
FILE
Library Browser
LIBRARY
Log Signals
Add Viewer
PREPARE
Stop Time
60
Normal
Fast Restart
Step Back
Run
Step Forward
Stop
SIMULATE
Data Inspector
REVIEW RES...
nnpc_project
nnpc_project
NN Predictive Controller
Reference
Optim.
Control Signal
Plant Output
NN Model
Random Reference
Flow Rate
Concentration
X(2Y) Graph
Block Parameters: Random Reference
Uniform Random Number
Output a uniformly distributed random signal. Output is repeatable for a given seed.
Parameters
Minimum:
-0.8
Maximum:
0.8
Seed:
0
Sample time:
2
Interpret vector parameters as 1-D
OK
Cancel
Help
Apply
Block Parameters: X(2Y) Graph
X(2Y) scope. (mask)
X(2Y) scope using MATLAB graph window. First input is used as time base. Enter plotting ranges.
Parameters
x-min:
0
x-max:
60
y-min:
-1
y-max:
1
Sample time:
-1
OK
Cancel
Help
Apply
Ready
131%
ode45


Plant Identification
File Window Help
Plant Identification
Network Architecture
Size of Hidden Layer
2
No. Delayed Plant Inputs
1
Sampling Interval (sec)
0.1
No. Delayed Plant Outputs
1
Normalize Training Data
Training Data
Training Samples
10000
Limit Output Data
Maximum Plant Input
4
Maximum Plant Output
23
Minimum Plant Input
-4
Minimum Plant Output
20
Maximum Interval Value (sec)
3
Simulink Plant Model:
Browse
Minimum Interval Value (sec)
2
cstr
Erase Imported Data
Import Data
Export Data
Training Parameters
Training Epochs
200
Training Function
trainlm
Use Current Weights
Use Validation Data
Use Testing Data
Train Network
OK
Cancel
Apply
Your training data set has 10000 samples.
You can now train the network.

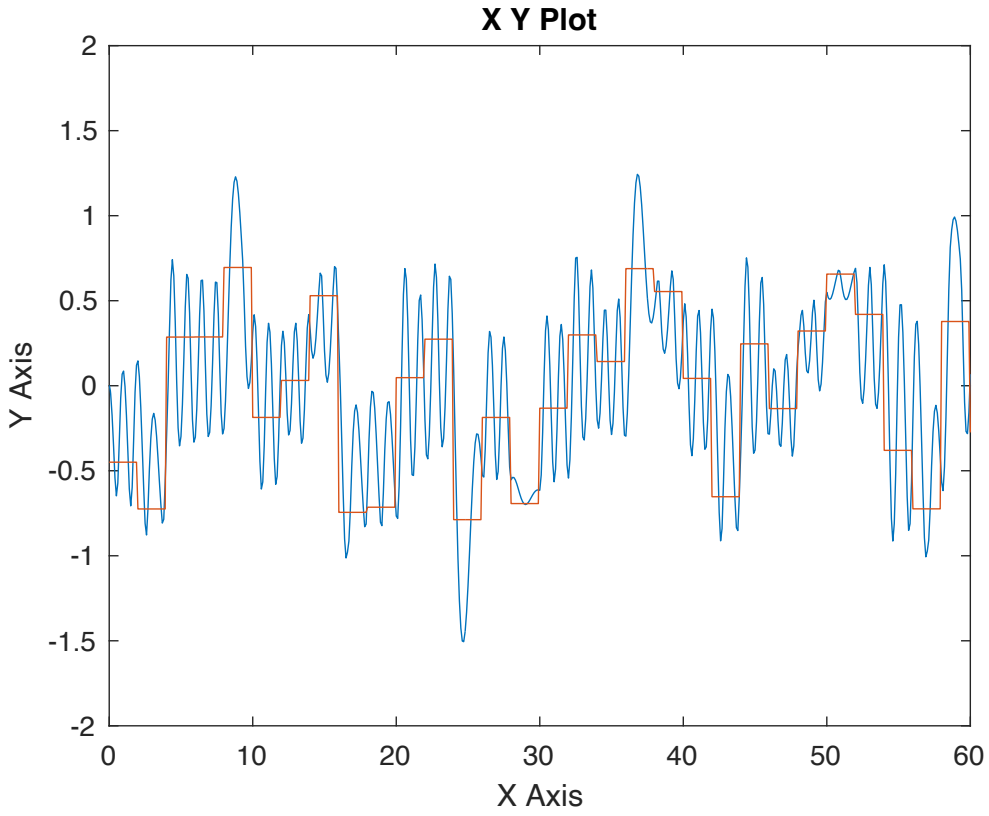

X Y Plot
Y Axis
X Axis
3
2
1
0
-1
-2
-3
0
10
20
30
40
50
60


Plant Identification
File Window Help
Plant Identification
Network Architecture
Size of Hidden Layer
7
Sampling Interval (sec)
0.1
No. Delayed Plant Inputs
2
No. Delayed Plant Outputs
2
Normalize Training Data
Training Data
Training Samples
10000
Limit Output Data
Maximum Plant Input
4
Maximum Plant Output
23
Minimum Plant Input
-4
Minimum Plant Output
20
Maximum Interval Value (sec)
3
Simulink Plant Model:
Browse
Minimum Interval Value (sec)
2
cstr
Erase Imported Data
Import Data
Export Data
Training Parameters
Training Epochs
1000
Training Function
trainlm
Use Current Weights
Use Validation Data
Use Testing Data
Train Network
OK
Cancel
Apply
Your training data set has 10000 samples.
You can now train the network.

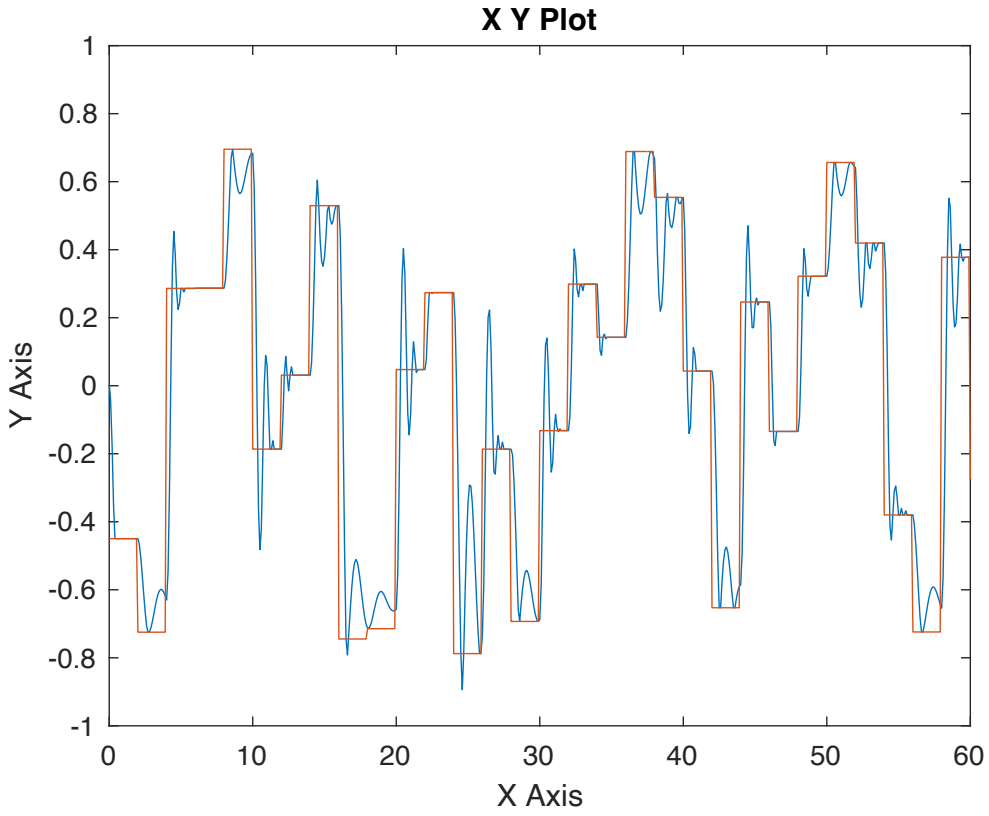

X Y Plot
Y Axis
X Axis
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
0
10
20
30
40
50
60

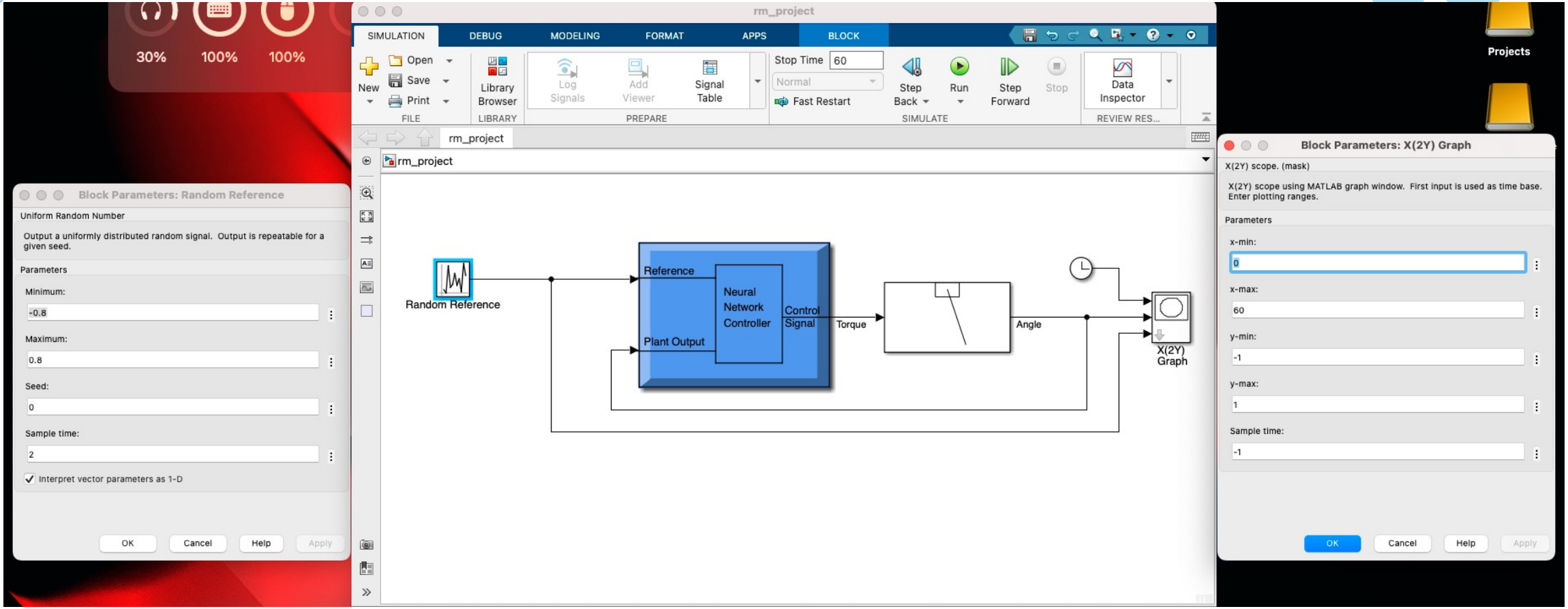

Block Parameters: Random Reference
Uniform Random Number
Output a uniformly distributed random signal. Output is repeatable for a given seed.
Parameters
Minimum:
-0.8
Maximum:
0.8
Seed:
0
Sample time:
2
Interpret vector parameters as 1-D
OK
Cancel
Help
Apply
narma_project
SIMULATION
DEBUG
MODELING
FORMAT
APPS
BLOCK
New
Open
Save
Print
FILE
Library Browser
LIBRARY
Log Signals
Add Viewer
PREPARE
Stop Time
60
Normal
Fast Restart
Step Back
Run
Step Forward
Stop
SIMULATE
Data Inspector
REVIEW RES...
narma_project
To create a connection, click a port, terminator, or line segment, and then click a compatible, highlighted model element. More information. Do not show again
Random Reference
Reference
f
g
Control Signal
Plant Output
Current
Position
X(2Y) Graph
Ready
100%
ode45
Block Parameters: X(2Y) Graph
X(2Y) scope. (mask)
X(2Y) scope using MATLAB graph window. First input is used as time base. Enter plotting ranges.
Parameters
x-min:
0
x-max:
60
y-min:
-1
y-max:
1
Sample time:
-1
OK
Cancel
Help
Apply

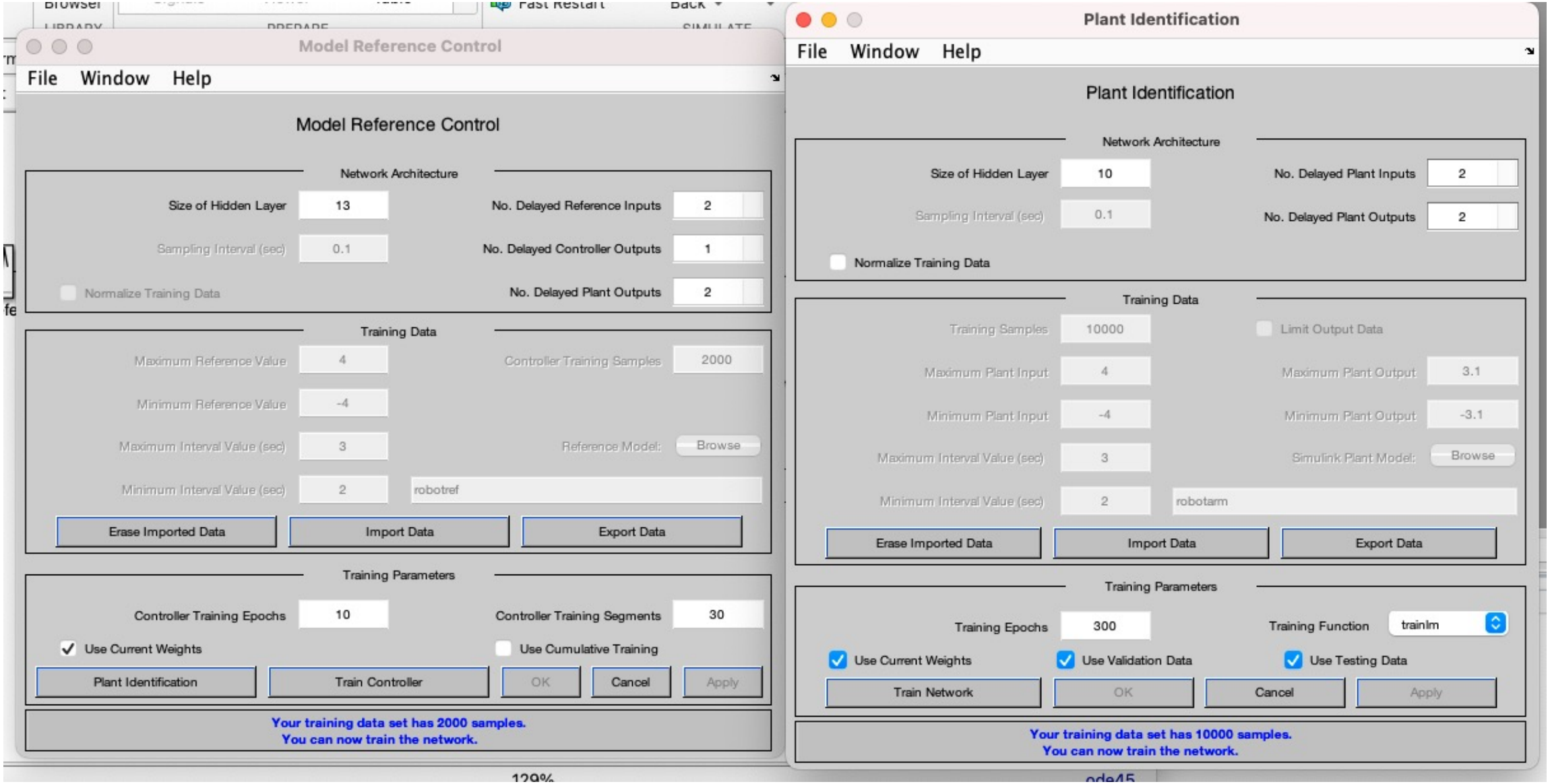

Plant Identification - NARMA-L2
File Window Help
Plant Identification - NARMA-L2
Network Architecture
Size of Hidden Layer
2
No. Delayed Plant Inputs
1
Sampling Interval (sec)
0.1
No. Delayed Plant Outputs
1
Normalize Training Data
Training Data
Training Samples
10000
Limit Output Data
Maximum Plant Input
4
Maximum Plant Output
Inf
Minimum Plant Input
-4
Minimum Plant Output
0
Maximum Interval Value (sec)
3
Simulink Plant Model:
Browse
Minimum Interval Value (sec)
2
ballrepel0
Erase Imported Data
Import Data
Export Data
Training Parameters
Training Epochs
200
Training Function
trainlm
Use Current Weights
Use Validation Data
Use Testing Data
Train Network
OK
Cancel
Apply
Your training data set has 10000 samples.
You can now train the network.

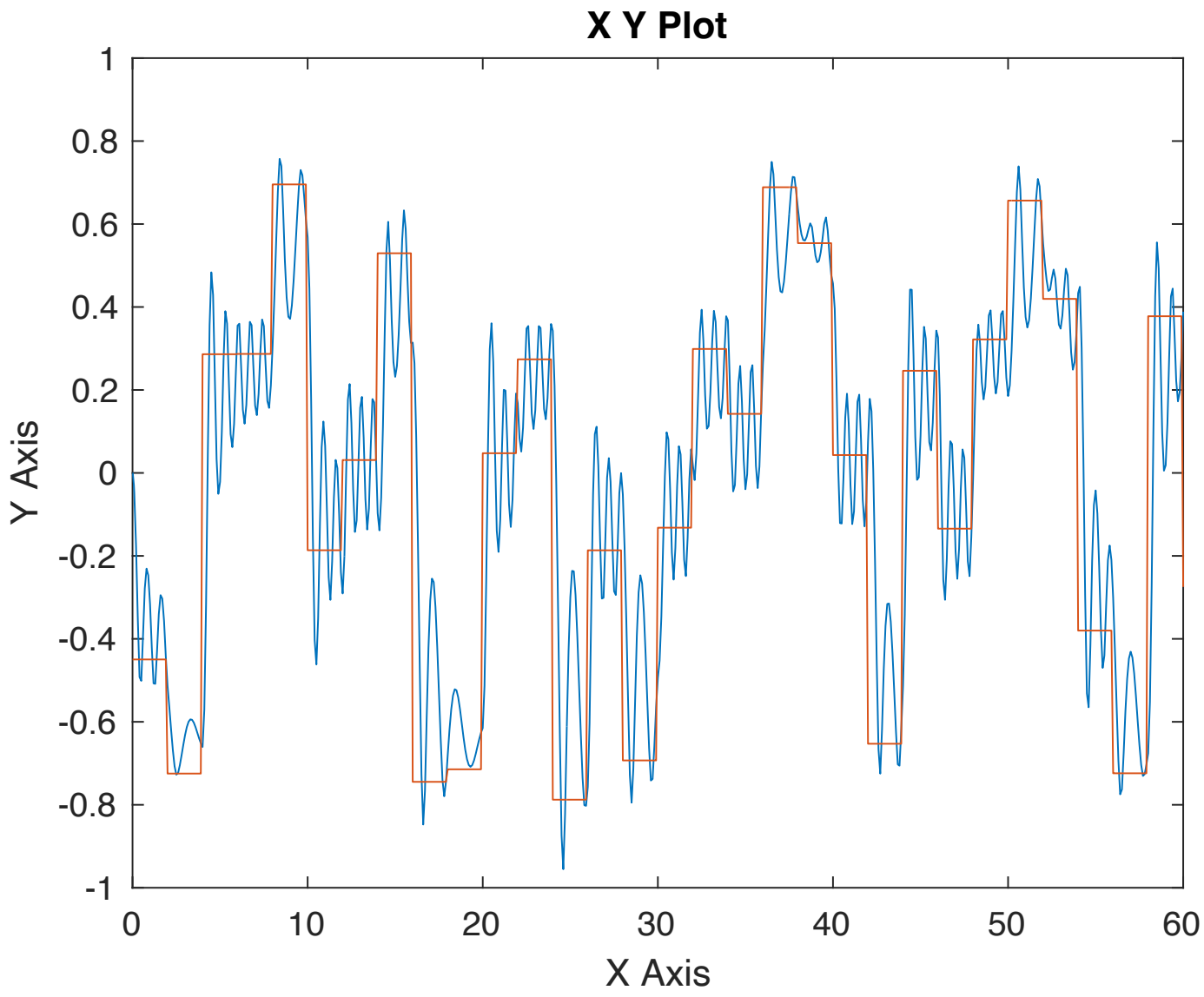

X Y Plot
Y Axis
X Axis
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
0
10
20
30
40
50
60

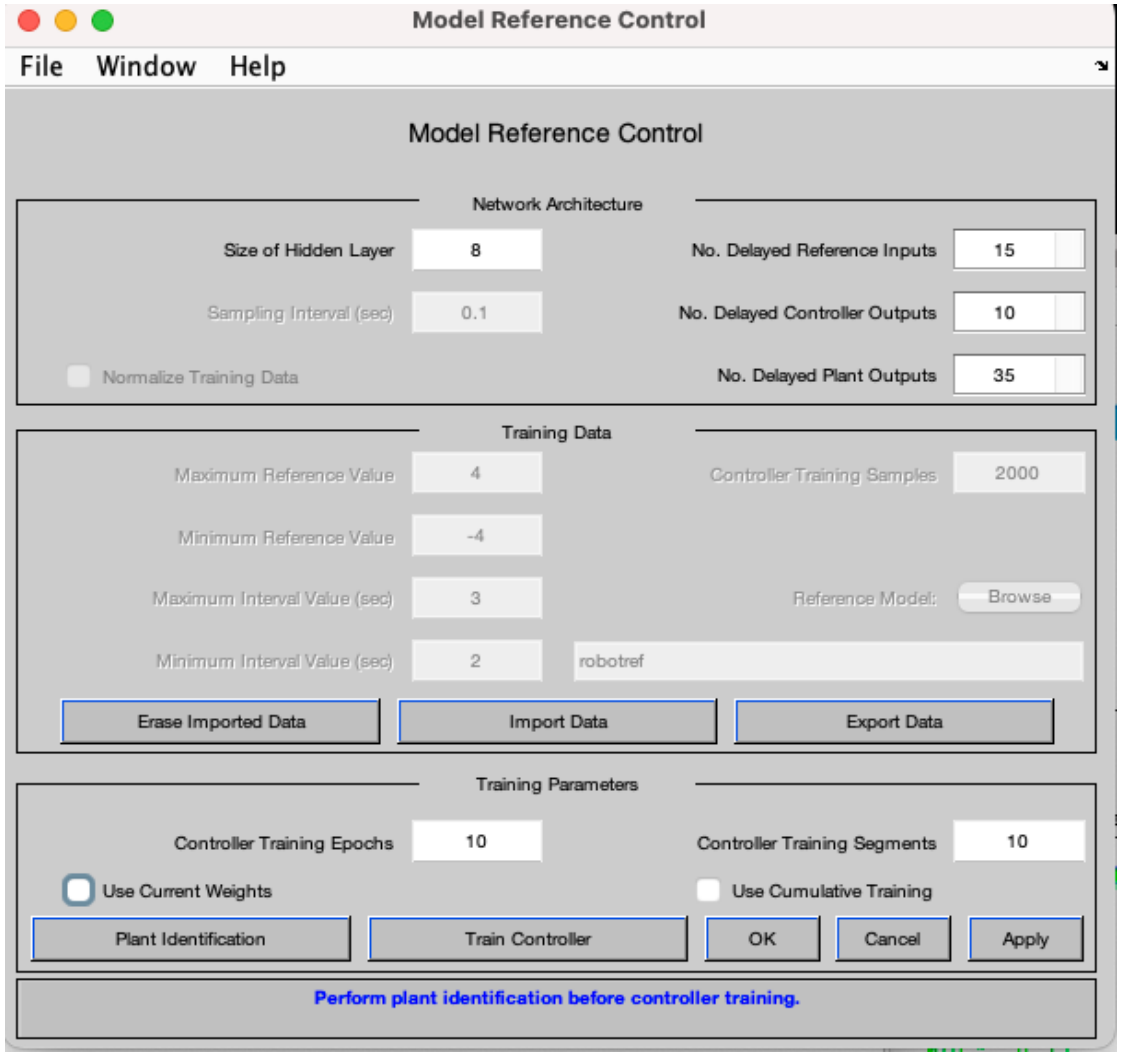

Plant Identification - NARMA-L2
File Window Help
Plant Identification - NARMA-L2
Network Architecture
Size of Hidden Layer
4
No. Delayed Plant Inputs
3
Sampling Interval (sec)
0.1
No. Delayed Plant Outputs
5
Normalize Training Data
Training Data
Training Samples
10000
Limit Output Data
Maximum Plant Input
4
Maximum Plant Output
Inf
Minimum Plant Input
-4
Minimum Plant Output
0
Maximum Interval Value (sec)
3
Simulink Plant Model:
Browse
Minimum Interval Value (sec)
2
ballrepel0
Erase Imported Data
Import Data
Export Data
Training Parameters
Training Epochs
1000
Training Function
trainlm
Use Current Weights
Use Validation Data
Use Testing Data
Train Network
OK
Cancel
Apply
Your training data set has 10000 samples.
You can now train the network.


X Y Plot
Y Axis
X Axis
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
0
10
20
30
40
50
60

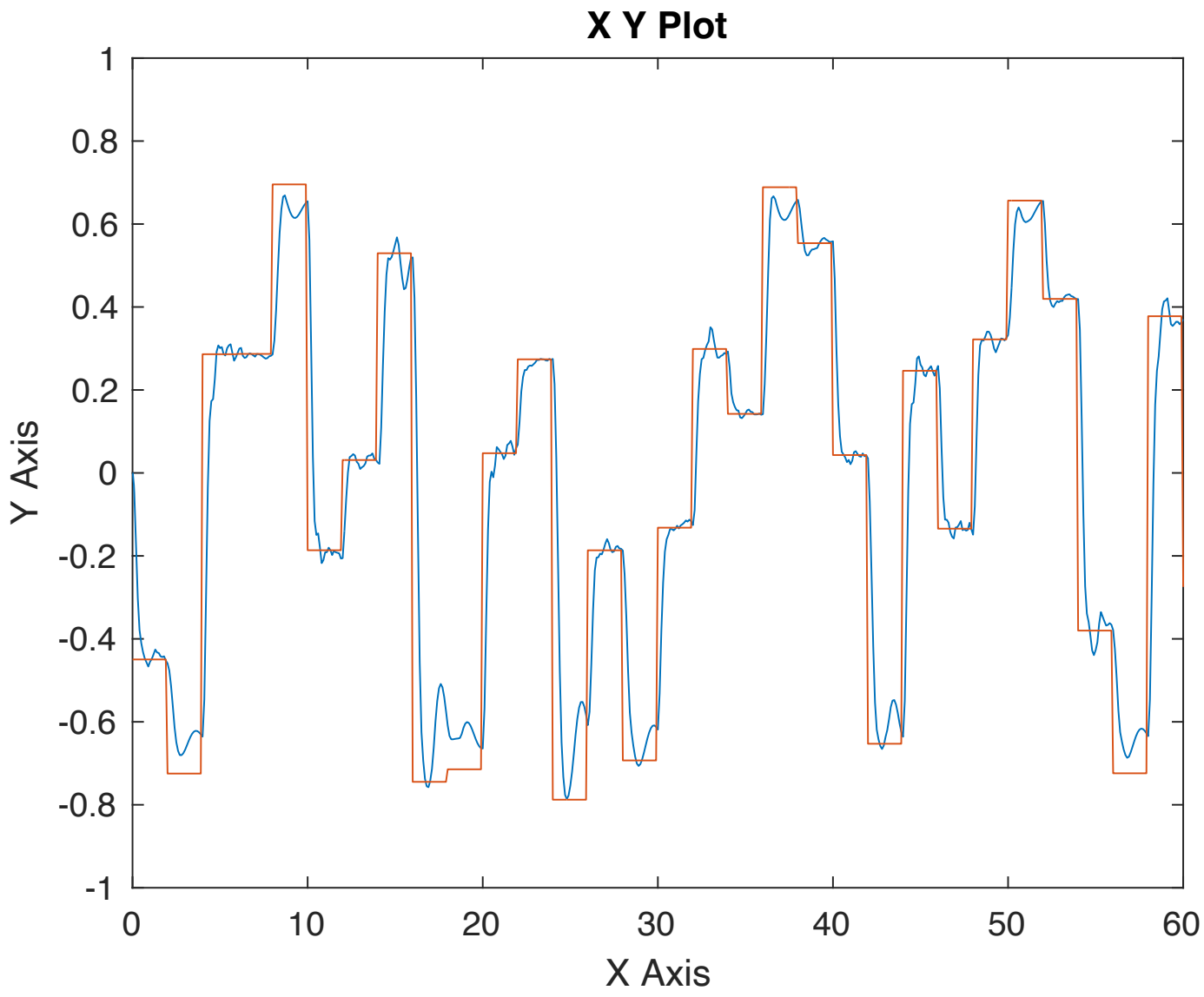

30%
100%
100%
rm_project
SIMULATION
DEBUG
MODELING
FORMAT
APPS
BLOCK
New
Open
Save
Print
FILE
Library Browser
LIBRARY
Log Signals
Add Viewer
Signal Table
PREPARE
Stop Time
60
Normal
Fast Restart
Step Back
Run
Step Forward
Stop
SIMULATE
Data Inspector
REVIEW RES...
rm_project
rm_project
Random Reference
Reference
Plant Output
Neural Network Controller
Control Signal
Torque
Angle
X(2Y) Graph
Projects
Block Parameters: Random Reference
Uniform Random Number
Output a uniformly distributed random signal. Output is repeatable for a given seed.
Parameters
Minimum:
-0.8
Maximum:
0.8
Seed:
0
Sample time:
2
Interpret vector parameters as 1-D
OK
Cancel
Help
Apply
Block Parameters: X(2Y) Graph
X(2Y) scope. (mask)
X(2Y) scope using MATLAB graph window. First input is used as time base. Enter plotting ranges.
Parameters
x-min:
0
x-max:
60
y-min:
-1
y-max:
1
Sample time:
-1
OK
Cancel
Help
Apply


Model Reference Control
File Window Help
Model Reference Control
Network Architecture
Size of Hidden Layer
13
No. Delayed Reference Inputs
2
Sampling Interval (sec)
0.1
No. Delayed Controller Outputs
1
Normalize Training Data
No. Delayed Plant Outputs
2
Training Data
Maximum Reference Value
4
Controller Training Samples
2000
Minimum Reference Value
-4
Maximum Interval Value (sec)
3
Reference Model:
Browse
Minimum Interval Value (sec)
2
robotref
Erase Imported Data
Import Data
Export Data
Training Parameters
Controller Training Epochs
10
Controller Training Segments
30
Use Current Weights
Use Cumulative Training
Plant Identification
Train Controller
OK
Cancel
Apply
Your training data set has 2000 samples.
You can now train the network.
Plant Identification
File Window Help
Plant Identification
Network Architecture
Size of Hidden Layer
10
No. Delayed Plant Inputs
2
Sampling Interval (sec)
0.1
No. Delayed Plant Outputs
2
Normalize Training Data
Training Data
Training Samples
10000
Limit Output Data
Maximum Plant Input
4
Maximum Plant Output
3.1
Minimum Plant Input
-4
Minimum Plant Output
-3.1
Maximum Interval Value (sec)
3
Simulink Plant Model:
Browse
Minimum Interval Value (sec)
2
robotarm
Erase Imported Data
Import Data
Export Data
Training Parameters
Training Epochs
300
Training Function
trainlm
Use Current Weights
Use Validation Data
Use Testing Data
Train Network
OK
Cancel
Apply
Your training data set has 10000 samples.
You can now train the network.

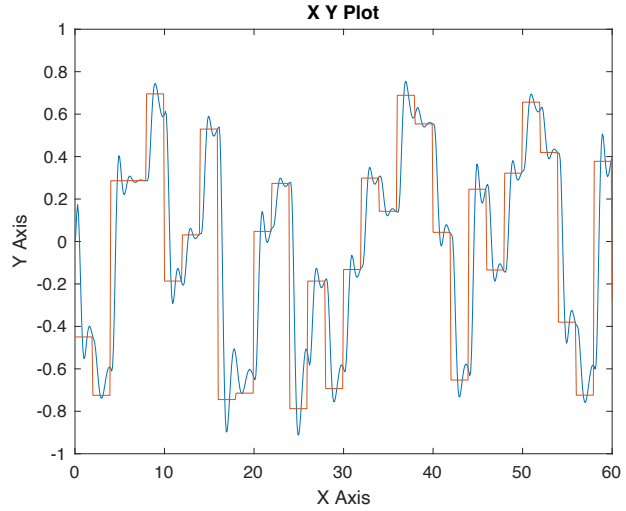

X Y Plot
Y Axis
X Axis
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
0
10
20
30
40
50
60

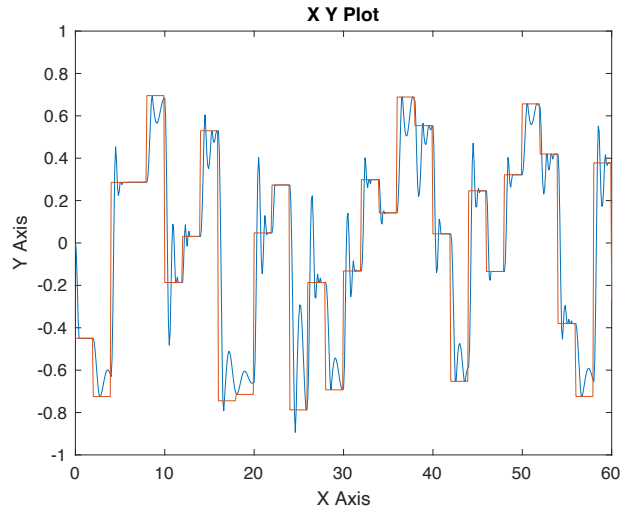

Model Reference Control
File Window Help
Model Reference Control
Network Architecture
Size of Hidden Layer
8
No. Delayed Reference Inputs
15
Sampling Interval (sec)
0.1
No. Delayed Controller Outputs
10
Normalize Training Data
No. Delayed Plant Outputs
35
Training Data
Maximum Reference Value
4
Controller Training Samples
2000
Minimum Reference Value
-4
Maximum Interval Value (sec)
3
Reference Model:
Browse
Minimum Interval Value (sec)
2
robotref
Erase Imported Data
Import Data
Export Data
Training Parameters
Controller Training Epochs
10
Controller Training Segments
10
Use Current Weights
Use Cumulative Training
Plant Identification
Train Controller
OK
Cancel
Apply
Perform plant identification before controller training.


Plant Identification
Network Architecture
Size of Hidden Layer
10
No. Delayed Plant Inputs
2
Sampling Interval (sec)
0.1
No. Delayed Plant Outputs
4
Normalize Training Data
Training Data
Training Samples
10000
Limit Output Data
Maximum Plant Input
4
Maximum Plant Output
3.1
Minimum Plant Input
-4
Minimum Plant Output
-3.1
Maximum Interval Value (sec)
3
Simulink Plant Model:
Browse
Minimum Interval Value (sec)
2
robotarm
Erase Imported Data
Import Data
Export Data
Training Parameters
Training Epochs
300
Training Function
trainlm
Use Current Weights
Use Validation Data
Use Testing Data
Train Network
OK
Cancel
Apply
Your training data set has 10000 samples.
You can now train the network.


X Y Plot
Y Axis
X Axis
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
0
10
20
30
40
50
60

Neural Network Predictive Controller





NARMAL2 Neural Controller

Model Reference Controller