System Identification

- **Data-based identification of dynamic systems**
  - Collect the input and output samples
    - U and Y
  - Perform system identification
    - H=arx([Y U],[n m d])
      - n=# of terms in a(z), m=#of terms in b(z), d=delay

- **Matlab Commands**

  idinput(): generates a pseudorandom binary sequence (PRBS) signal of length $k=2^N-1$, for use as an input signal for system identification

  arx(): identifies the autoregressive exogenous (ARX) model of a system from measured input-output data

  lsim(): simulates and finds the system output yk in response to an input signal uk defined over the time sequence tk

  ident: launches a GUI interface for system identification

System Identification

Example: Consider a system transfer function (assumed to be unknown)

$$G(s) = \frac{s^3 + 7s^2 + 11s + 5}{s^4 + 7s^3 + 21s^2 + 37s + 30}$$

System ID: find an estimate of G(s) using input-output measurements.

Identification process:

- Define the system's transfer function (for simulation only):
  s=tf('s'); Gs=(s^3+7*s^2+11*s+5)/(s^4+7*s^3+21*s^2+37*s+30);

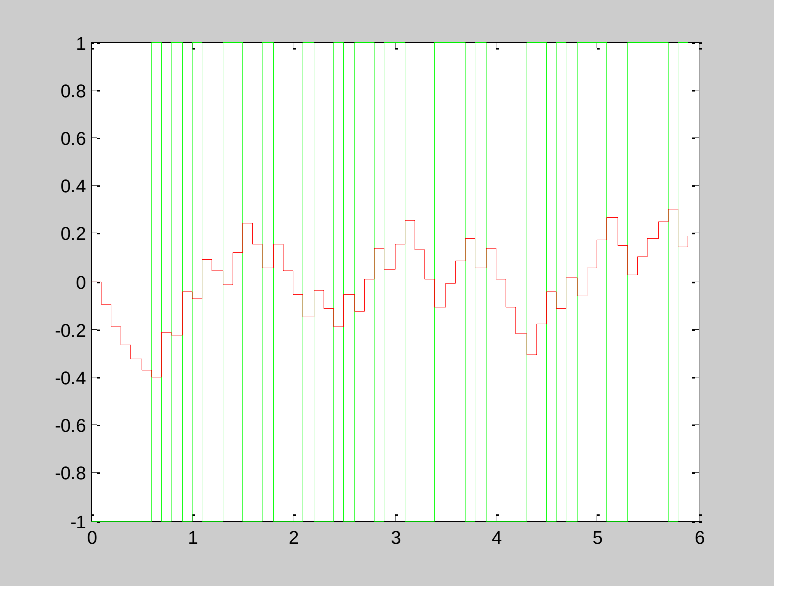
- Discretize the system model, with sample time Ts=0.1 sec:
  Ts=0.1; Gz=c2d(Gs,Ts),

- Simulate the system with a sufficiently exciting input (rich in frequency), such as pseudo-random binary sequence (**PRBS**) or **chirp** function, to excite all system modes, and collect the I/O data:
  N=6; Ns=2^(N-1)-1; Tf=Ns*Ts;
  t=0:Ts:Tf;
  uk=idinput(Ns,'prbs');
  yk=lsim(G,uk,t);

Identification process …

- Plot the collected I/O data:
  (for **PRBS** input)

```
figure(1), stairs(t,uk,'g'); hold on,
stairs(t,yk,'r'); hold off,
```



- Find an auto-regressive exogenous (ARX) model of the system of order (4,4,1):

```
arx441=arx([yk, uk], [4 4 1]);
G1=tf(arx441); Ghz=G1(1); Ghz.Ts=0.2; Ghs=d2c(G1),
```

The resulting transfer function estimate is:

$\hat{G}(s) = \dfrac{s^3+7s^2+11s+5}{s^4+7s^3+21s^2+37s+30}$, which is identified very accurately.

System Identification Using PRBS Function

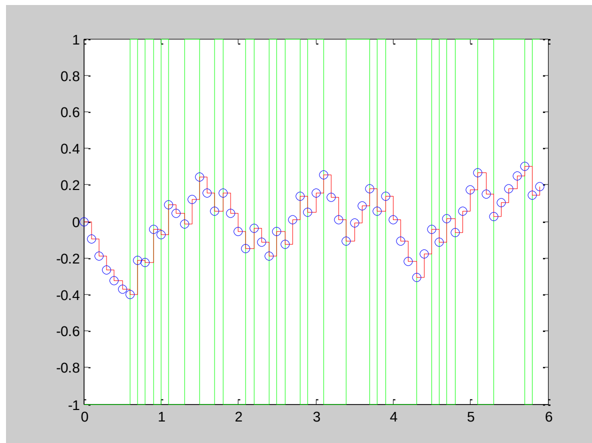
PRBS function (sufficiently exciting)

Transfer function estimate:

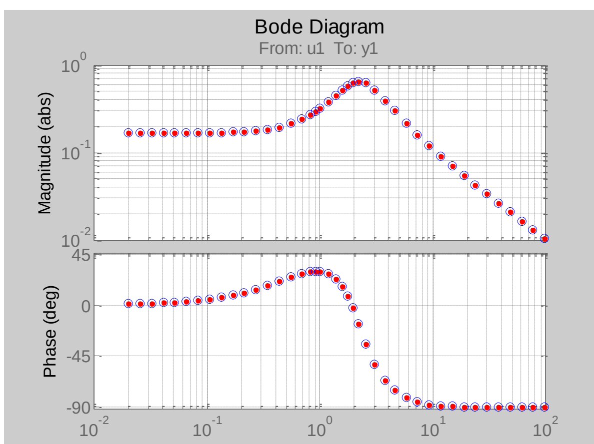
$$\hat{G}(s) = \frac{s^3+7s^2+11s+5}{s^4+7s^3+21s^2+37s+30}$$

(very accurate)

System response plot:



Bode plot:




```
% Simulate the unknown system
clear all, clc,
s=tf('s');
disp('G(s) = '),
Gs=(s^3+7*s^2+11*s+5)...
   /(s^4+7*s^3+21*s^2+37*s+30),
% Collect the input/output data
Ts=0.1; Ns=60; Tf=(Ns-1)*Ts;
disp('G(z) = '),
Gz=c2d(Gs,Ts),
t=0:Ts:Tf;
uk=idinput(Ns,'PRBS');
%uk=chirp(t,0,Tf,5)';
%uk=sin(2*pi*1*t)';
yk=lsim(Gz,uk,t);
figure(1), stairs(t,uk,'g'); hold on,
stairs(t,yk,'r'); hold off,
% Estimate the system’s TF
YUk=iddata(yk,uk,Ts);
arx441=arx(YUk,[4,4,1]);
disp('Gh(z) = '),
Gz441=tf(arx441);
Gzh=Gz441(1),
disp('Gh(s) = '),
Gsh=d2c(Gzh)
yhk=lsim(Gzh,uk,t);
figure(2), stairs(t,uk,'g'); hold on,
stairs(t,yk,'r'); plot(t,yhk,'bo'); hold off,
figure(3), bode(Gs,'r.',Gsh,'bo'),
```

System Identification Using Chirp Function

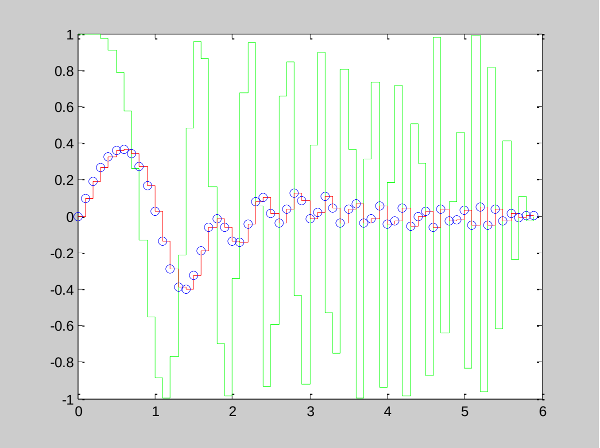
Chirp function (sufficiently exciting)

Transfer function estimate:

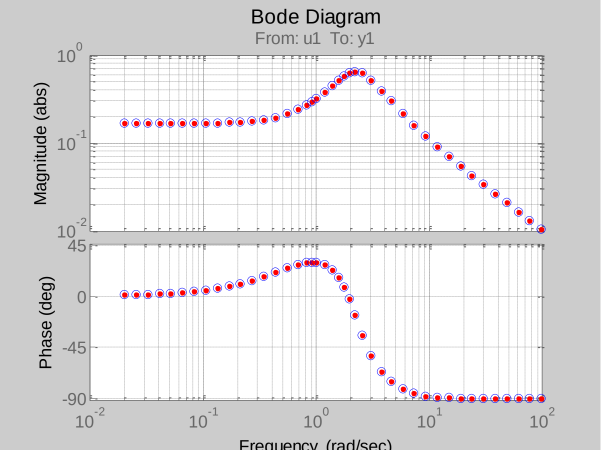
$$\hat{G}(s) = \frac{s^3+7s^2+11s+5}{s^4+7s^3+21s^2+37s+30}$$

(very accurate)

System response plot:



Bode plot:




```
% Simulate the unknown system
clear all, clc,
s=tf('s');
disp('G(s) = '),
Gs=(s^3+7*s^2+11*s+5)...
   /(s^4+7*s^3+21*s^2+37*s+30),
% Collect the input/output data
Ts=0.1; Ns=60; Tf=(Ns-1)*Ts;
disp('G(z) = '),
Gz=c2d(Gs,Ts),
t=0:Ts:Tf;
%uk=idinput(Ns,'PRBS');
uk=chirp(t,0,Tf,5)';
%uk=sin(2*pi*1*t)';
yk=lsim(Gz,uk,t);
figure(1), stairs(t,uk,'g'); hold on,
stairs(t,yk,'r'); hold off,
% Estimate the system's TF
YUk=iddata(yk,uk,Ts);
arx441=arx(YUk,[4,4,1]);
disp('Gh(z) = '),
Gz441=tf(arx441);
Gzh=Gz441(1),
disp('Gh(s) = '),
Gsh=d2c(Gzh)
yhk=lsim(Gzh,uk,t);
figure(2), stairs(t,uk,'g'); hold on,
stairs(t,yk,'r'); plot(t,yhk,'bo'); hold off,
figure(3), bode(Gs,'r.',Gsh,'bo'),
```

System Identification Using Sine Function

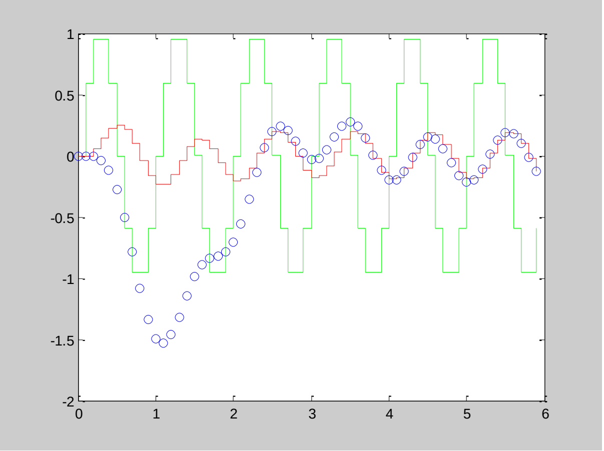
Sine function (not sufficiently exciting)

Transfer function estimate:

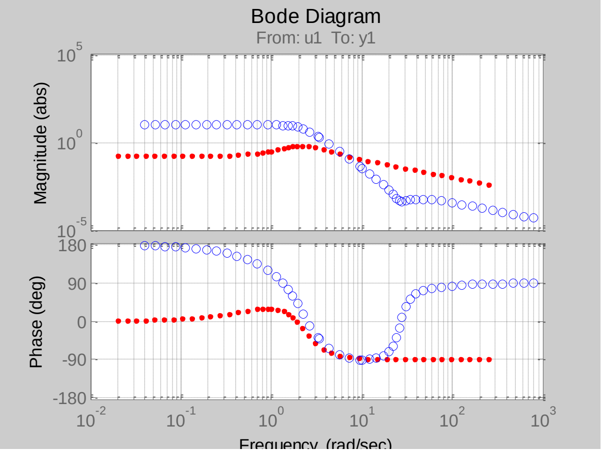
$$\hat{G}(s) = \frac{s^3+7s^2+11s+5}{s^4+7s^3+21s^2+37s+30}$$

(not accurate)

System response plot:



Bode plot:

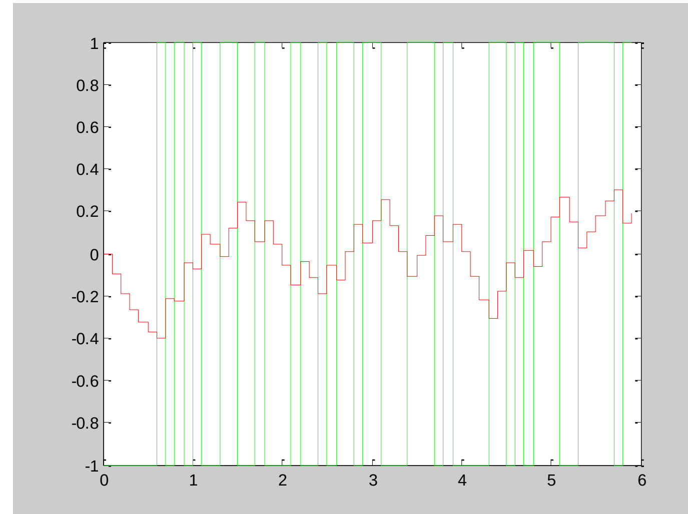



```
% Simulate the unknown system
clear all, clc,
s=tf('s');
disp('G(s) = '),
Gs=(s^3+7*s^2+11*s+5)...
   /(s^4+7*s^3+21*s^2+37*s+30),
% Collect the input/output data
Ts=0.1; Ns=60; Tf=(Ns-1)*Ts;
disp('G(z) = '),
Gz=c2d(Gs,Ts),
t=0:Ts:Tf;
%uk=idinput(Ns,'PRBS');
%uk=chirp(t,0,Tf,5)';
uk=sin(2*pi*1*t)';
yk=lsim(Gz,uk,t);
figure(1), stairs(t,uk,'g'); hold on,
stairs(t,yk,'r'); hold off,
% Estimate the system's TF
YUk=iddata(yk,uk,Ts);
arx441=arx(YUk,[4,4,1]);
disp('Gh(z) = '),
Gz441=tf(arx441);
Gzh=Gz441(1),
disp('Gh(s) = '),
Gsh=d2c(Gzh)
yhk=lsim(Gzh,uk,t);
figure(2), stairs(t,uk,'g'); hold on,
stairs(t,yk,'r'); plot(t,yhk,'bo'); hold off,
figure(3), bode(Gs,'r.',Gsh,'bo'),
```

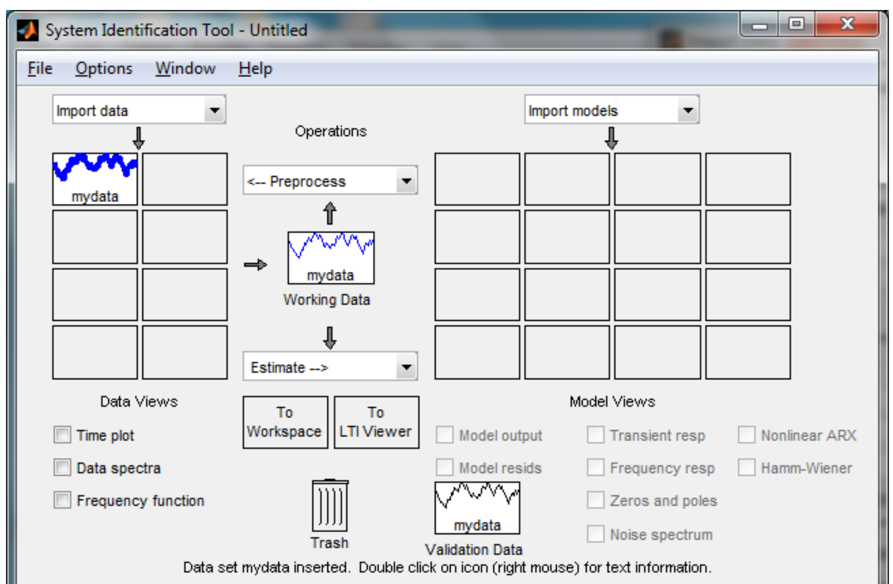
System Identification Using “Sys-ID” GUI

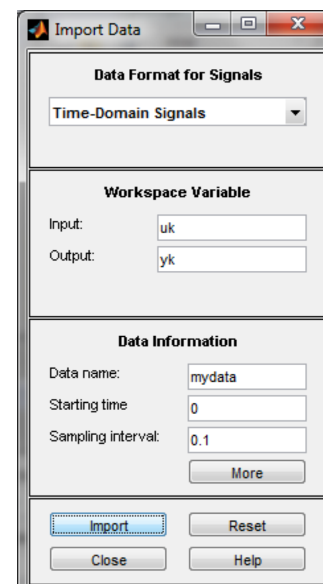
Identification process:

- Simulate the system with a sufficiently exciting input, and collect the I/O data.



- Launch the system identification GUI
  - Type “**ident**” in Matlab workspace
- Import data >> Time domain data…
  - Insert I/O data names, uk, yk,
  - Insert Starting time and Sampling interval, and then import

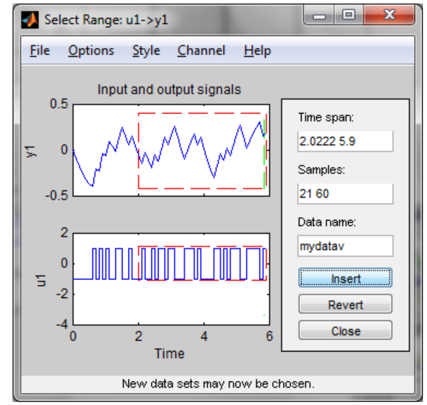


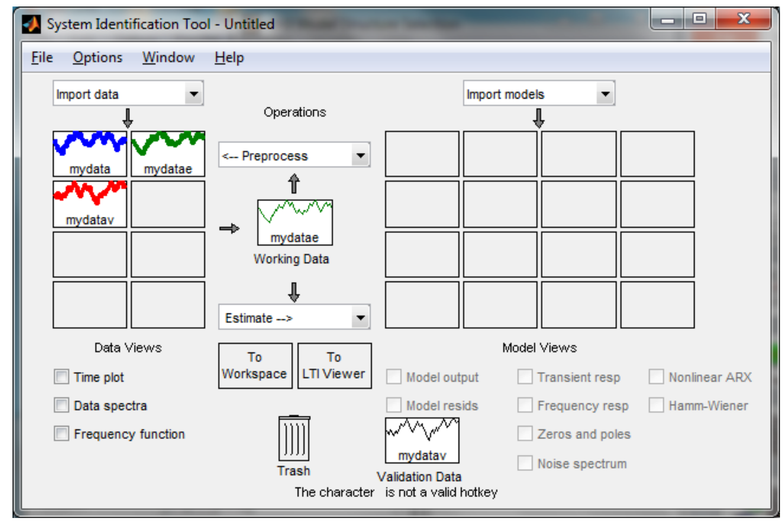


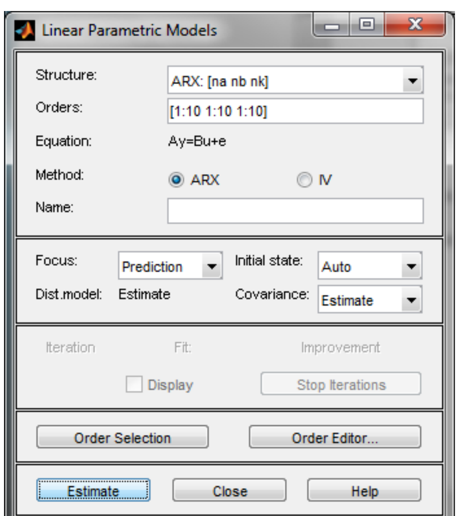
System Identification Using “Sys-ID” GUI

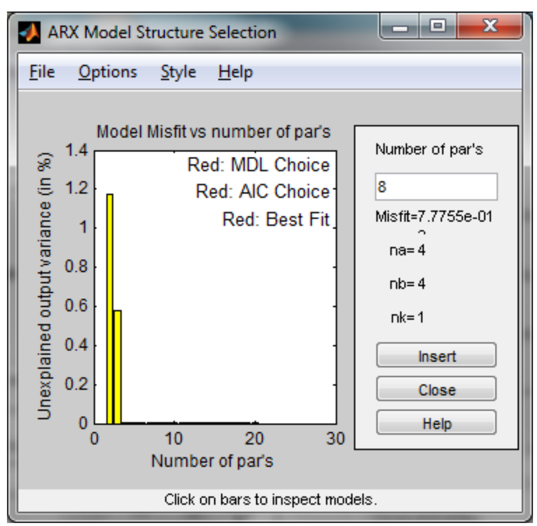
Identification process…

- Set Preprocess >> Select range…
  - Select the range of ‘mydatae’ for estimation and ‘mydatav’ for validation
- Drag and drop “mydatae” into Working Data field and “mydatav” into Validation Data field
- Select Estimate … >> Linear parametric models…
- Click Order Selection, and then Estimate





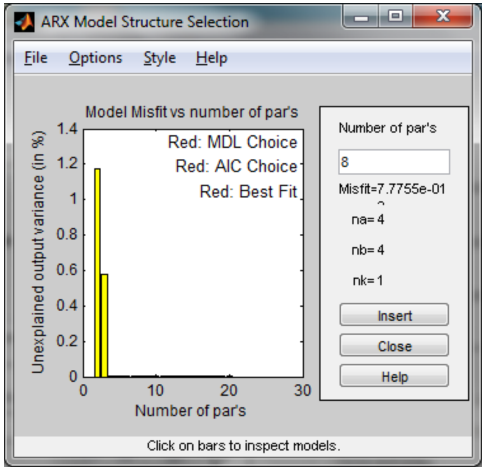


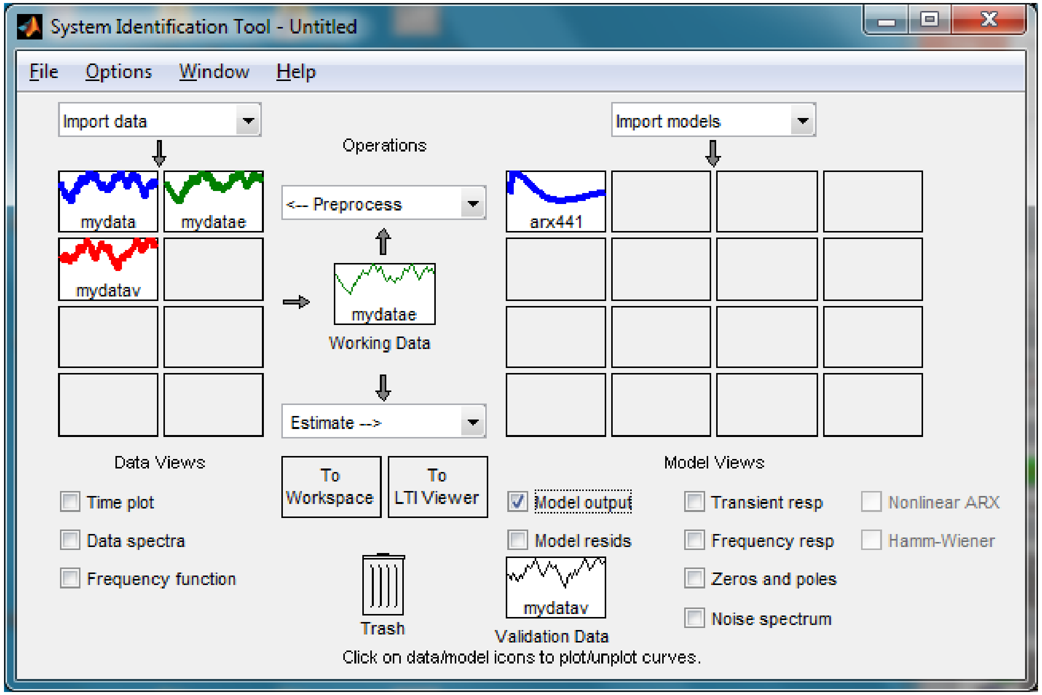


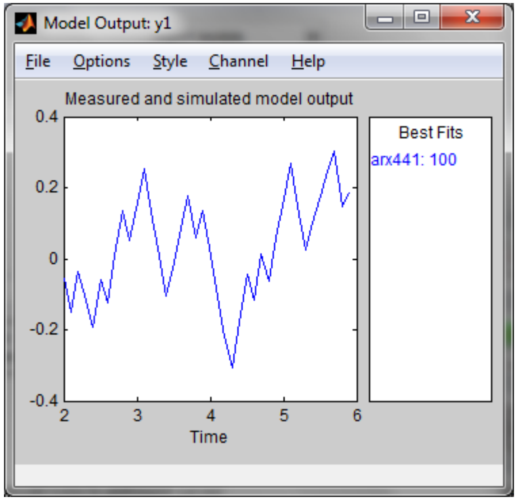
System Identification Using "Sys-ID" GUI

Identification process…

- Click "Insert" to get the best fit model (in this example, the arx441 model) into SYS-ID GUI
- Check "Model output" field
  - You should see arx441: %100 fit





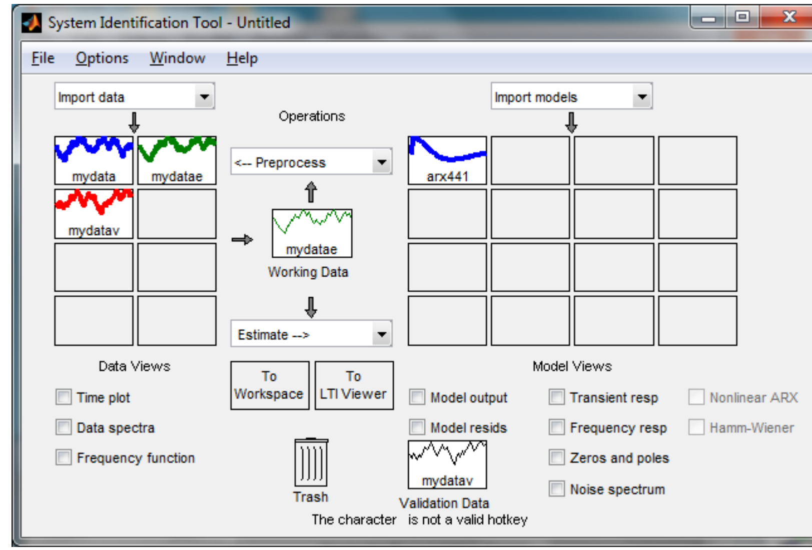


System Identification Using “Sys-ID” GUI

Identification process…

- Drag and drop arx441 model object to “To Workspace” field
  - You should then see the ‘arx441’ object in the Matlab workspace

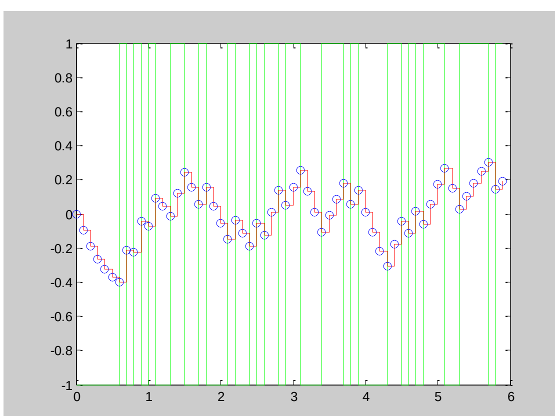
- From arx441 in Matlab find the transfer function estimate (as before).



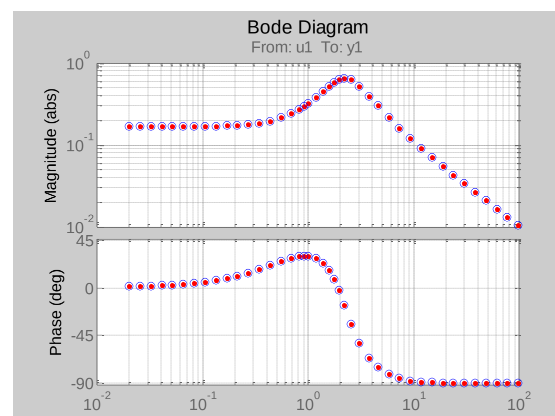
Transfer function estimate:

$$\hat{G}(s) = \frac{s^3+7s^2+11s+5}{s^4+7s^3+21s^2+37s+30}$$

System response plot



Bode plot



System Identification Using “Sys-ID” GUI

For more information, visit:

http://www.mathworks.com/help/releases/R2014a/ident/index.html