The dynamics of in acuator joint space is written as

$$M\ddot{q} + C\dot{q} + G = Au - Kq - D\dot{q} + \Delta$$

where

$$q = [\theta_1, l_1, \theta_2, l_2]^T, u = [\tau_{y1}, f_{z1}, \tau_{y2}, f_{z2}]^T, diag(A) = [a_1, a_2, a_3, a_4], diag(K) = [k_1, k_2, k_3, k_4], diag(D) = [d_1, d_2, d_3, d_4]$$

Δ contains all unmodeled dynamics.

For segment i

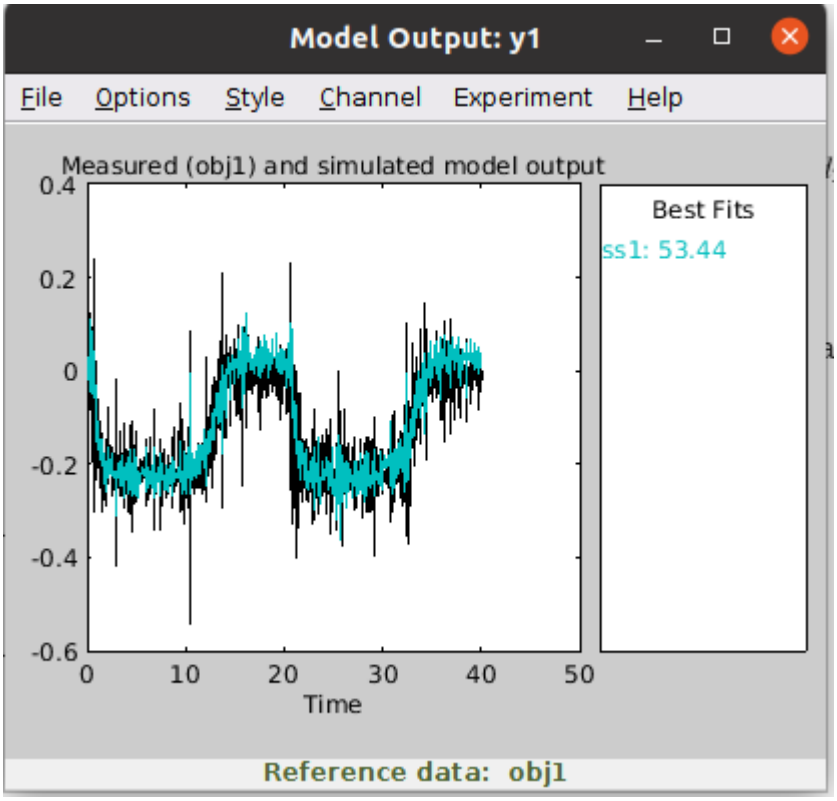
$$\theta_i = (Encoder_{i1} - Encoder_{i2})/0.04, l_i = (Encoder_{i1} - Encoder_{i2})/2$$

$$\tau_{yi} = pd_{i1} - pd_{i2}, f_{zi} = pd_{i1} + pd_{i2} + pd_{i3}$$

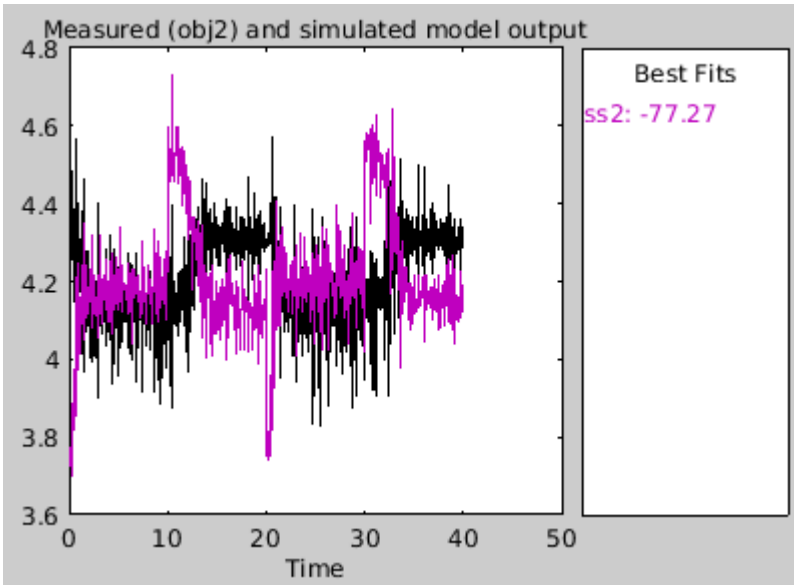
Least-square

We set $y = M\ddot{q} + C\dot{q} + G$, then $y_i = a_i u_i - k_i q_i - d_i \dot{q}_i$ and apply 0-order state space model to find the parameter

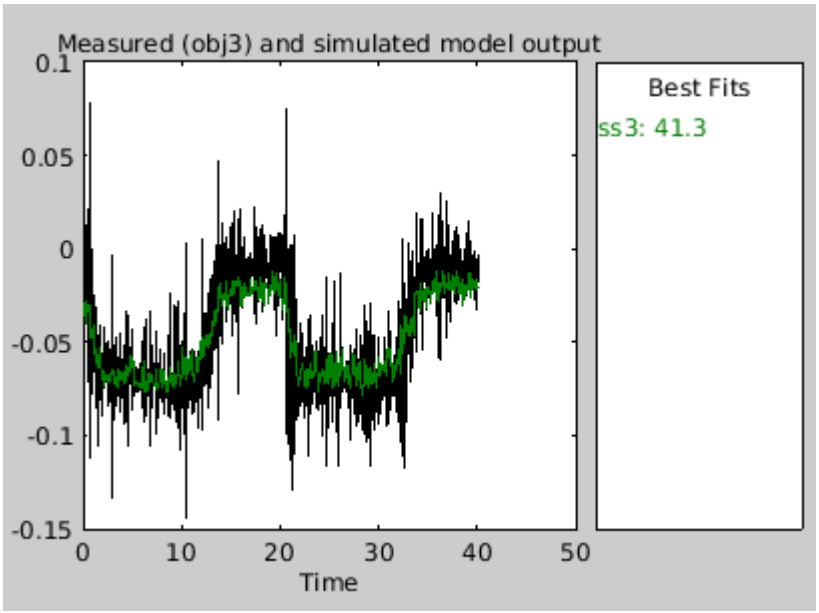
theta1 result



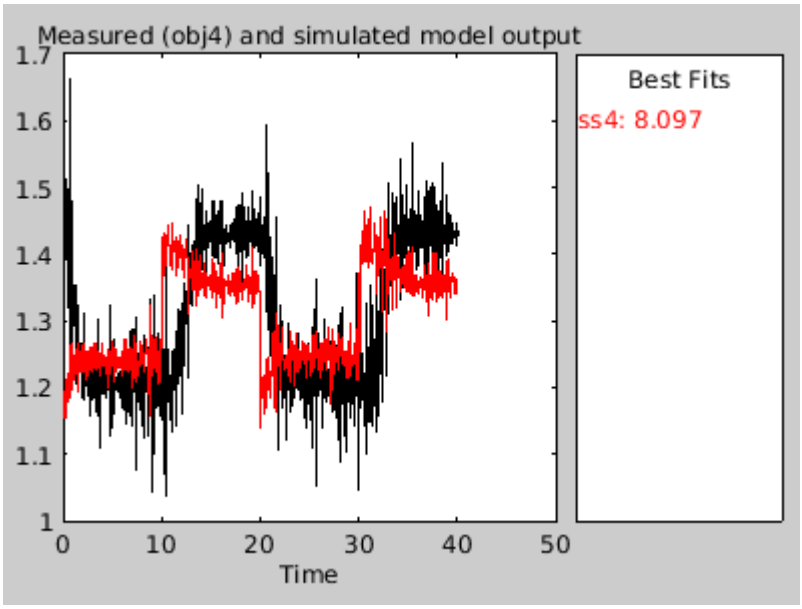
l1 result



theta2 result



l2 result

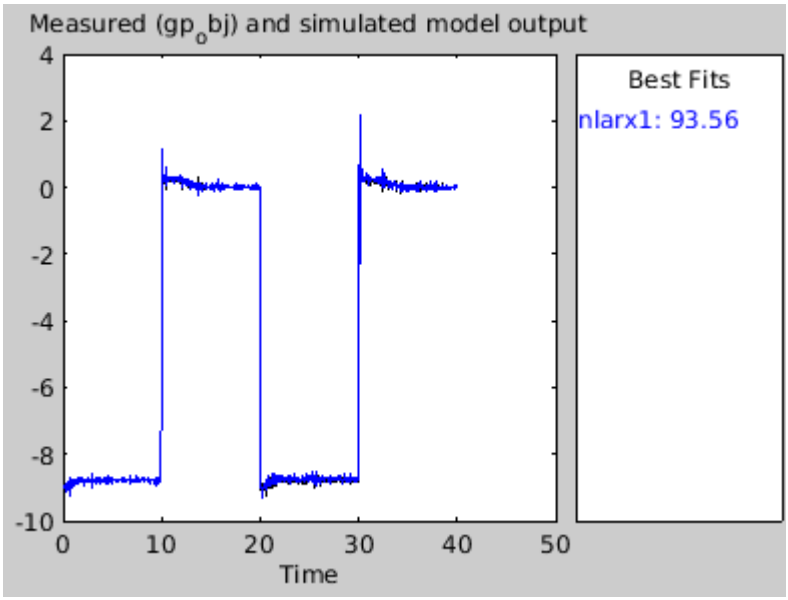


NARX

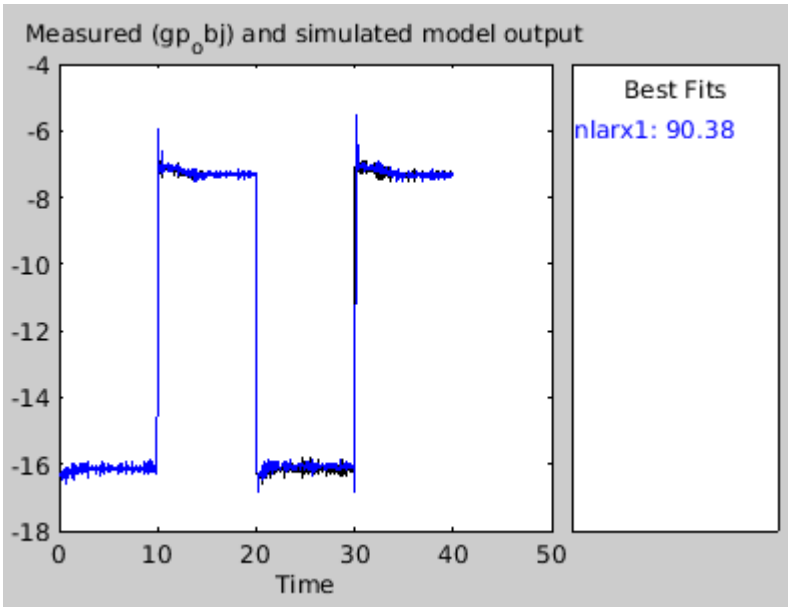
We re-write $N = u - M\ddot{q} + C\dot{q} + G = Kq + D\dot{q} + \Delta$, then $\widehat{N} = GP(q, \dot{q}, u)$ and the complete dynamics is $M\ddot{q} + C\dot{q} + G - \widehat{N} = u$

Sample size 1202 at 30Hz, and only one trial is used.

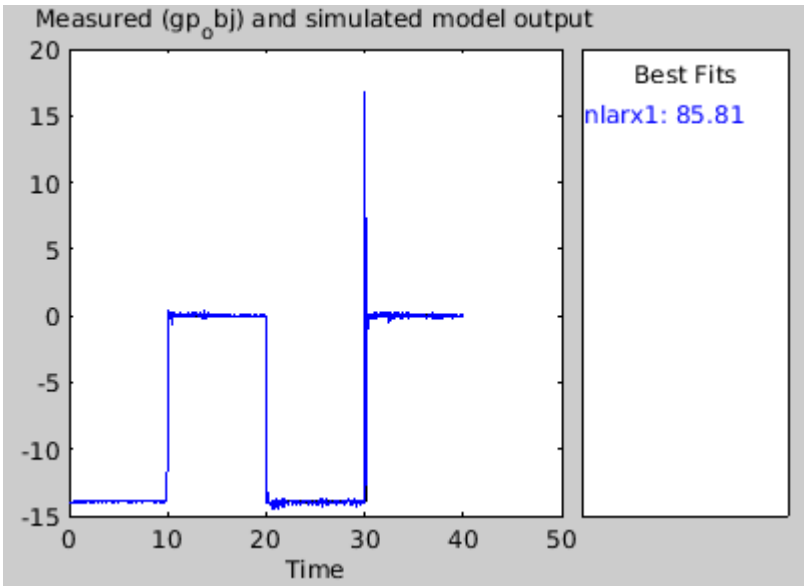
N(1,1)



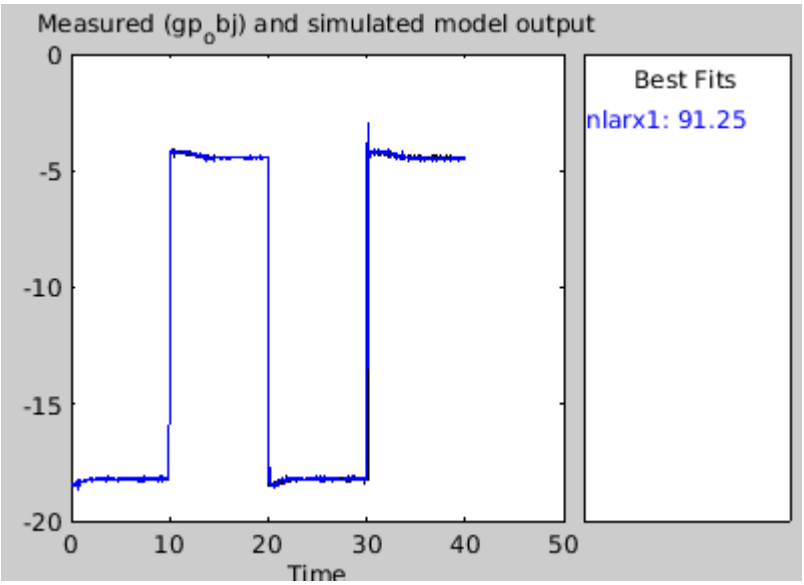
N(2,1)


Measured (gp_obj) and simulated model output
-4
-6
-8
-10
-12
-14
-16
-18
0
10
20
30
40
50
Time
Best Fits
nlarx1: 90.38

N(3,1)


Measured (gp_obj) and simulated model output
20
15
10
5
0
-5
-10
-15
0
10
20
30
40
50
Time
Best Fits
nlarx1: 85.81

N(4,1)



GREYBOX-1

Use greybox sysid with inputs = u, outputs = q, num_para = 12

Error message

```
Warning: Model simulation infeasible. Check parameter
values.
Error using iddata/nlgreyest
The specified model parameters or states are
infeasible for simulation. Verify that the model's
ODE file ("funcGreyBoxOde2seg_part2") can be
simulated with the given parameters and initial
states values.
```

GREYBOX-2

Use greybox sysid with inputs = u, outputs = $[q, \dot{q}]^T$, num_para = 12