ME 494/5594 – Robotics Systems Identification

HW #3 Due Wednesday, September 14th, 2022

You will be using data collected from the Quanser Qube (motor with encoder) for HW #3. Use the file 'sweep_5v_300s.mat' **and** 'qube_data_multistep.mat' for the experimental data, see below for the breakdown of the data.

Row 1: Time, collected at 100 Hz
Row 2: Input Command in Volts (maximum for this device is +/- 10V)
Row 3: Angle, radians
Row 4: Angular velocity, radians/second

1. **OLS:** Estimate a model using OLS of the Qube motion for **both** input files. Use the angular acceleration as your dependent variable (z). You will need to use deriv.m to calculate the angular acceleration. Show your model structure (with estimated coefficients and coefficient uncertainties) for both input files. How well do the coefficients match between the two input files? **Use the same model structure for both input files.** Show a plot of the model output and the actual vs. time. Add the <u>confidence bounds</u> onto the model output. Provide your <u>Coefficient of Determination</u> (quality of your fit).

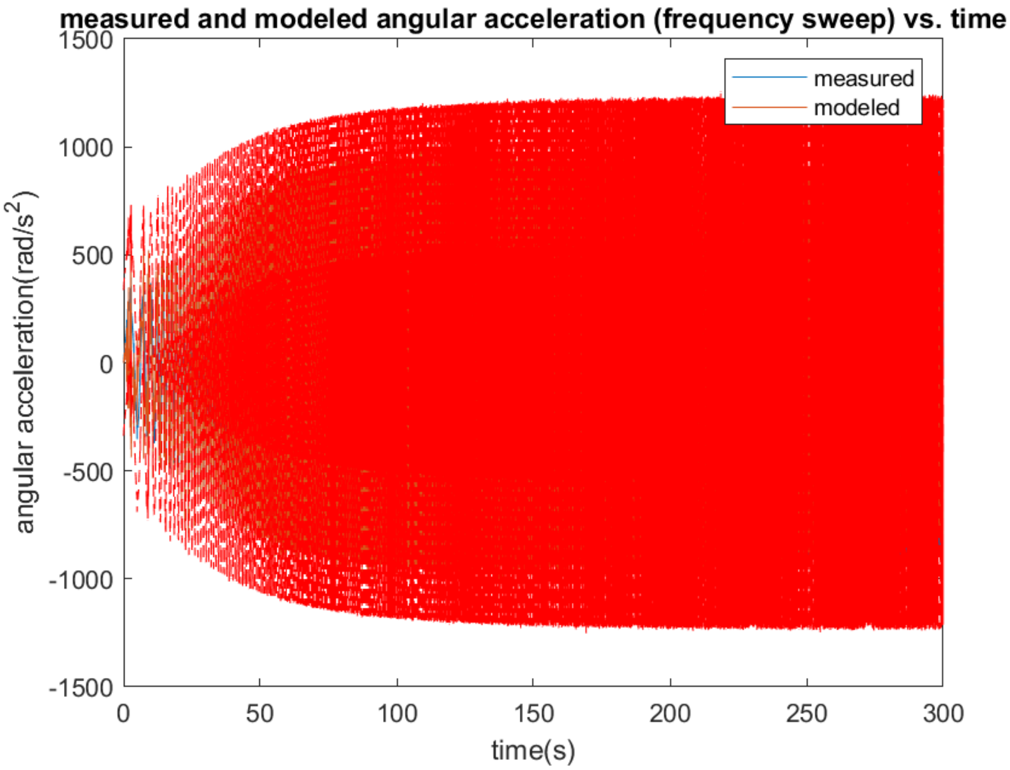
   model structure for the frequency sweep is:

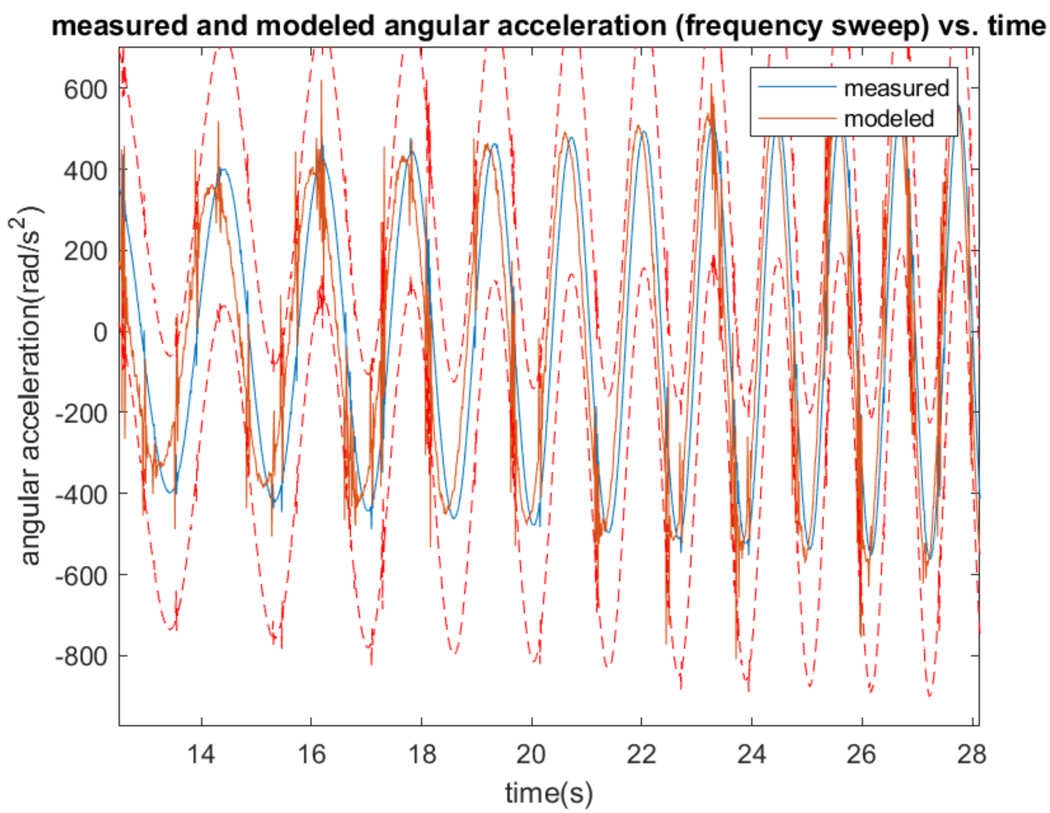
   Y_hat = .0255*Time + 173.271*Voltage -.0243*Angle - 5.1593*Velocity

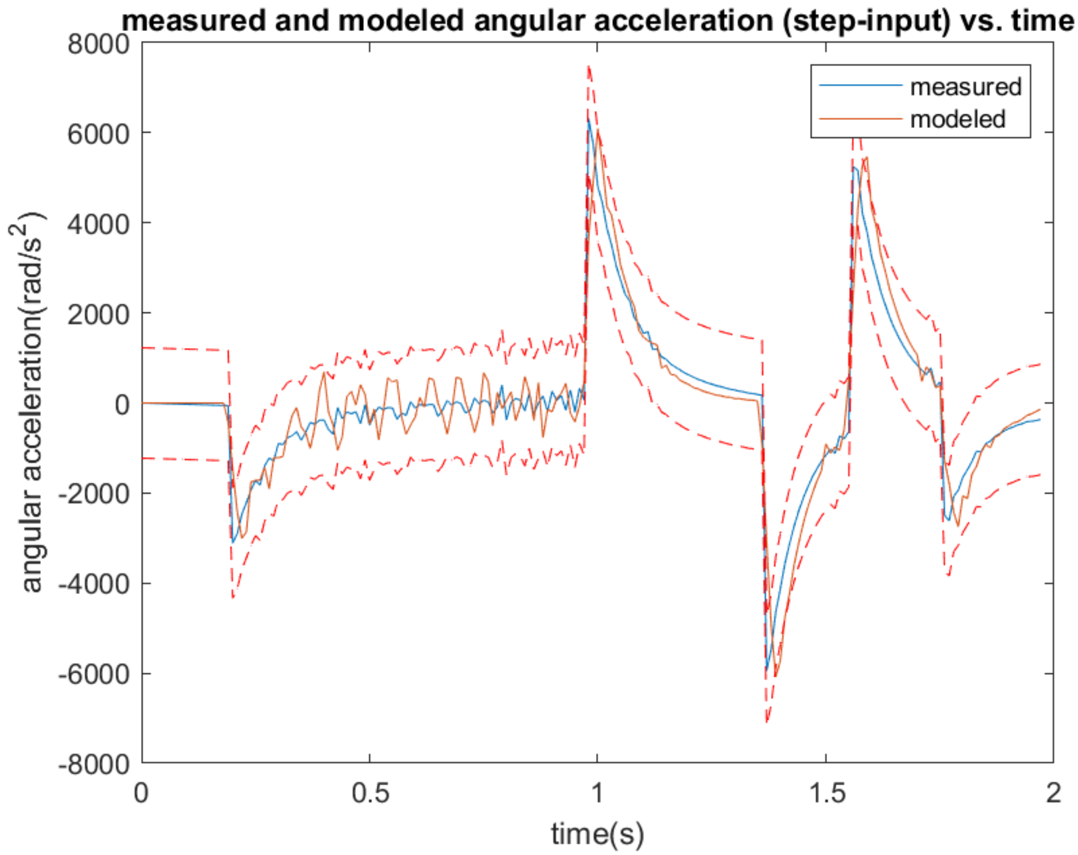
   model structure for the step input is:

   Y_hat = -297.625*Time + 406.9984*Voltage - 3.0379*Angle - 10.1334*Velocity

   The Time coefficients are vastly different. Voltage has similar sized coefficients. The angle coefficients are approximately 2 orders of magnitude different.


measured and modeled angular acceleration (frequency sweep) vs. time
measured
modeled
angular acceleration(rad/s^2)
time(s)


measured and modeled angular acceleration (frequency sweep) vs. time
measured
modeled
angular acceleration(rad/s^2)
time(s)



The frequency sweep R squared value is:

R_sq =

0.9226

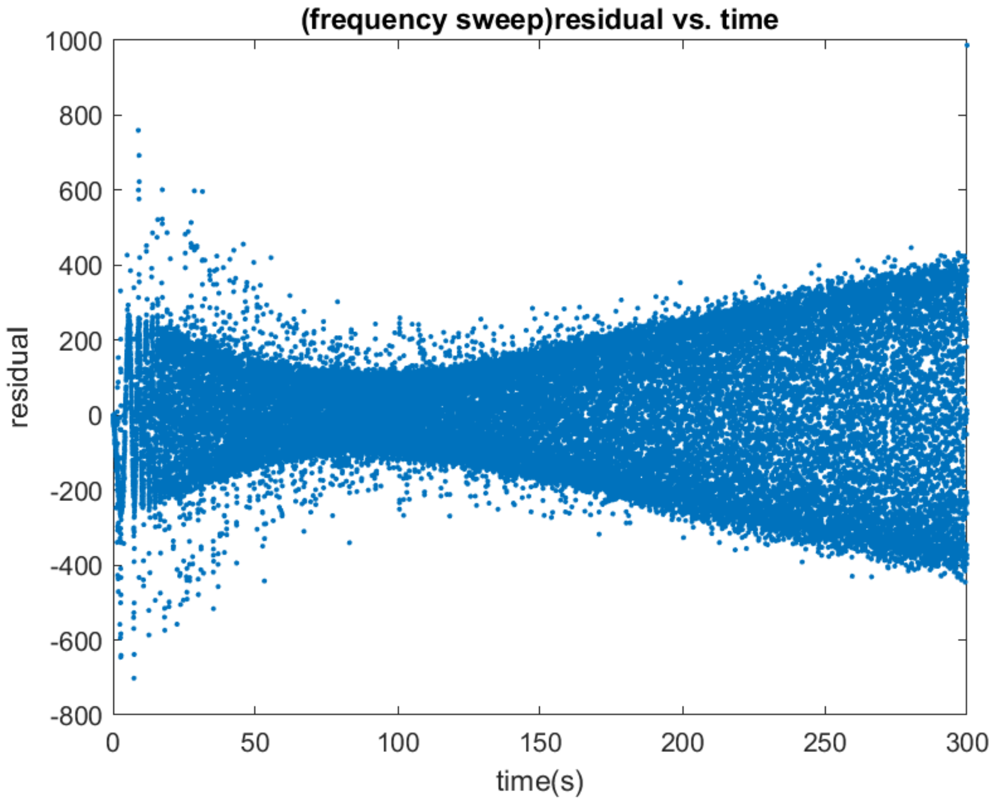
The step input R squared value is:

R_sq2 =

0.8866

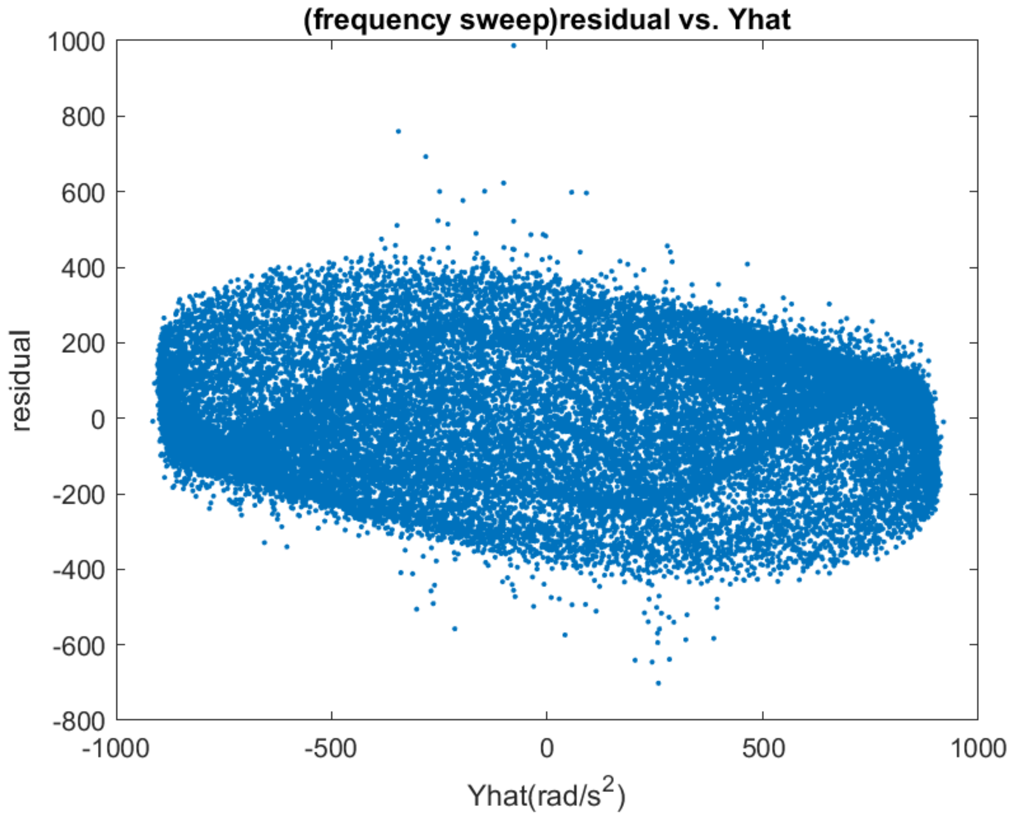
Since the frequency sweep dataset was so large and compact I decided to show a close up view as well.

2. **Residuals:** Analyze the residuals (2 plots) as we have discussed in class for both input files. Comment on your results. If there are any issues, comment on potential ways to address them.

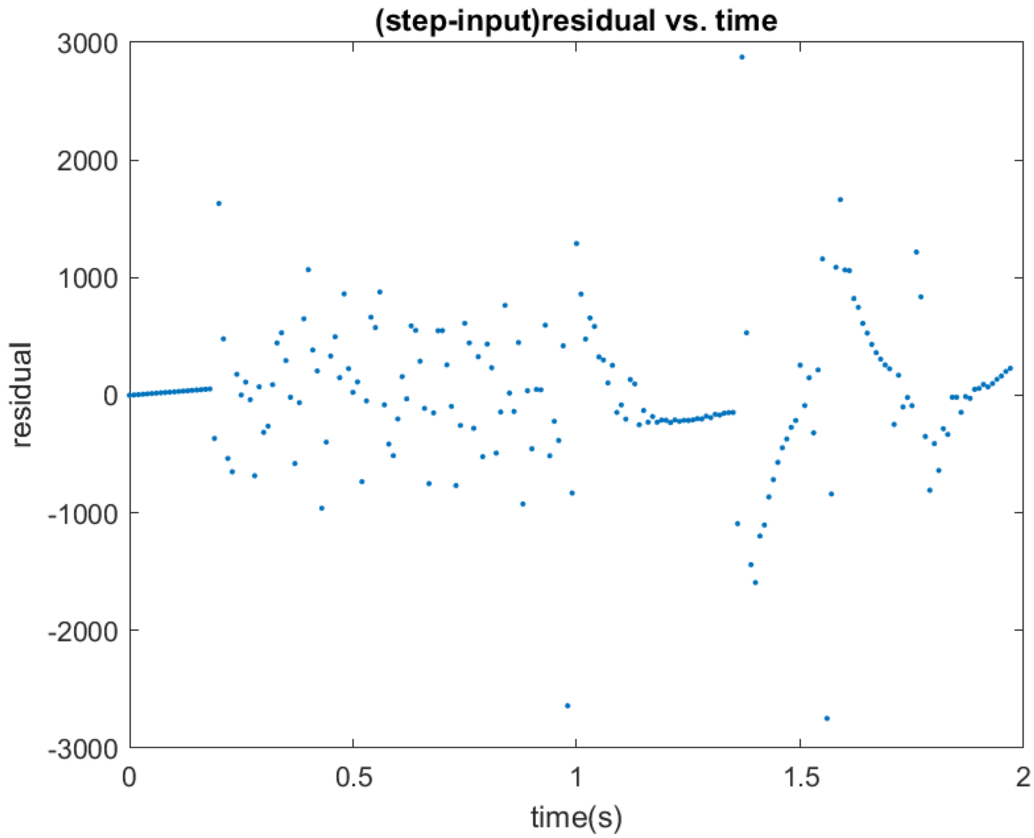


From 0 to 100 seconds the residual shinks and from 100 to 300 seconds the residual grows.

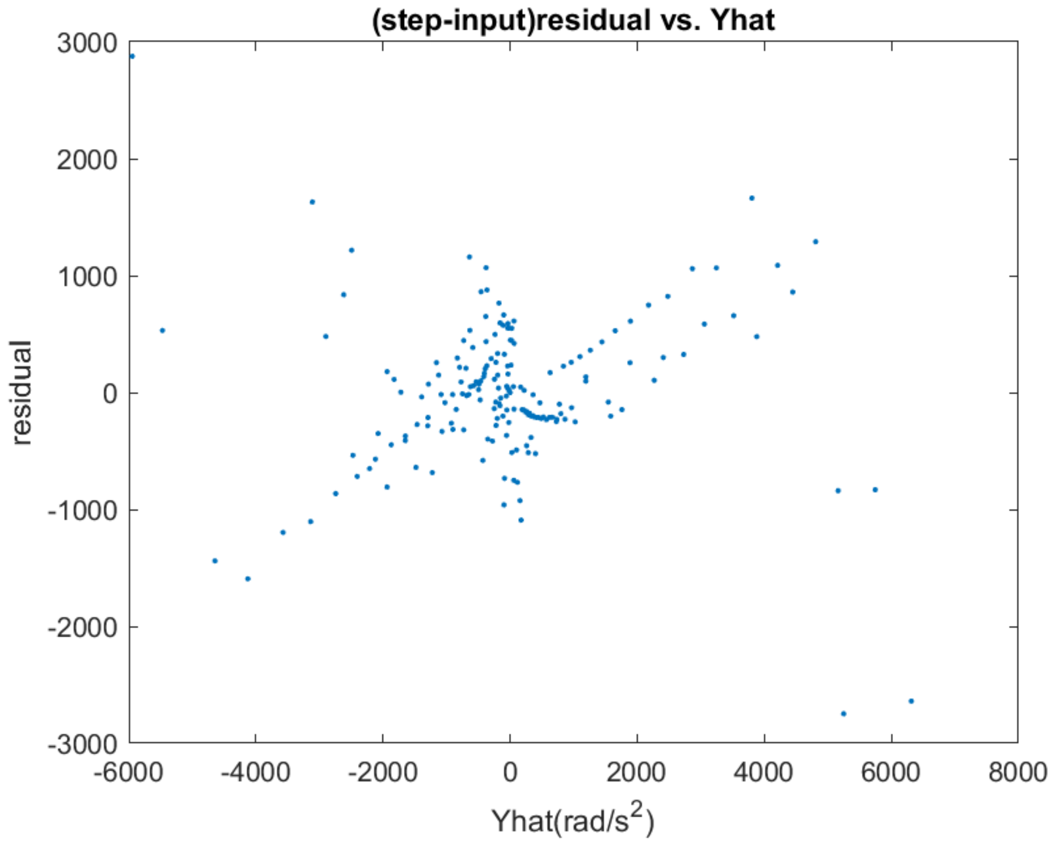
This is likely from a missing component in the model.



Residual is relatively constant as Y_hat grows.



The residual looks random. I believe this means that the model is decent.



It appears that the residual grows and shrinks with Y_hat.

3. **Normalized Regressor:** Using your final model structure, normalize your regressor matrix and your dependent variable for both input files. Show your normalized estimated parameters, what do you see in the relative importance of the parameters? What differences do you see between the two sets of normalized regressors?

   normalized estimated parameters (frequency Sweep)=

   time: 0.0034

   voltage: 1.0111

   angle: 0.0024

   angular velocity: -0.3143

   normalized estimated parameters (step-input)=

time: -0.1058

voltage: 1.4756

angle: -0.0975

angular velocity: -1.1311

In both models voltage and angular velocity had the highest relative importantance and relative importance of time and angle was low. The ratios between each normalized estimated parameters were quite different between both models.

4. **Collinearity:** With the normalized regressor matrix, calculate the correlation coefficient matrix for each input file. Comment on what you can see in the context of **collinearity** within the matrix for each input data type. Calculate both R^2 (from VIF) and condition number (SVD method).

correlation coefficient matrix (frequency sweep) =

1.0000	-0.0134	0.2421	-0.0311
-0.0134	1.0000	-0.1526	0.3112
0.2421	-0.1526	1.0000	-0.0978
-0.0311	0.3112	-0.0978	1.0000

For the model generated from the frequency sweep data the estimated parameters were not highly correlated. The strongest correlation is between the time and angular velocity, at 31%.

R2 =

0.0594

0.1126

0.0830

0.0997

condition number =

1.0000

1.6037

3.6059

4.6217

correlation coefficient matrix (step input) =

1.0000	0.4363	-0.6512	0.4816
0.4363	1.0000	-0.4151	0.7864
-0.6512	-0.4151	1.0000	-0.2291
0.4816	0.7864	-0.2291	1.0000

For the model generated from the step input data the estimated parameters were highly correlated. The strongest correlation is between the voltage and angular velocity, at 79%.

R2 (step input) =

0.5588

0.6895

0.5336

0.6991

condition number (step input)=

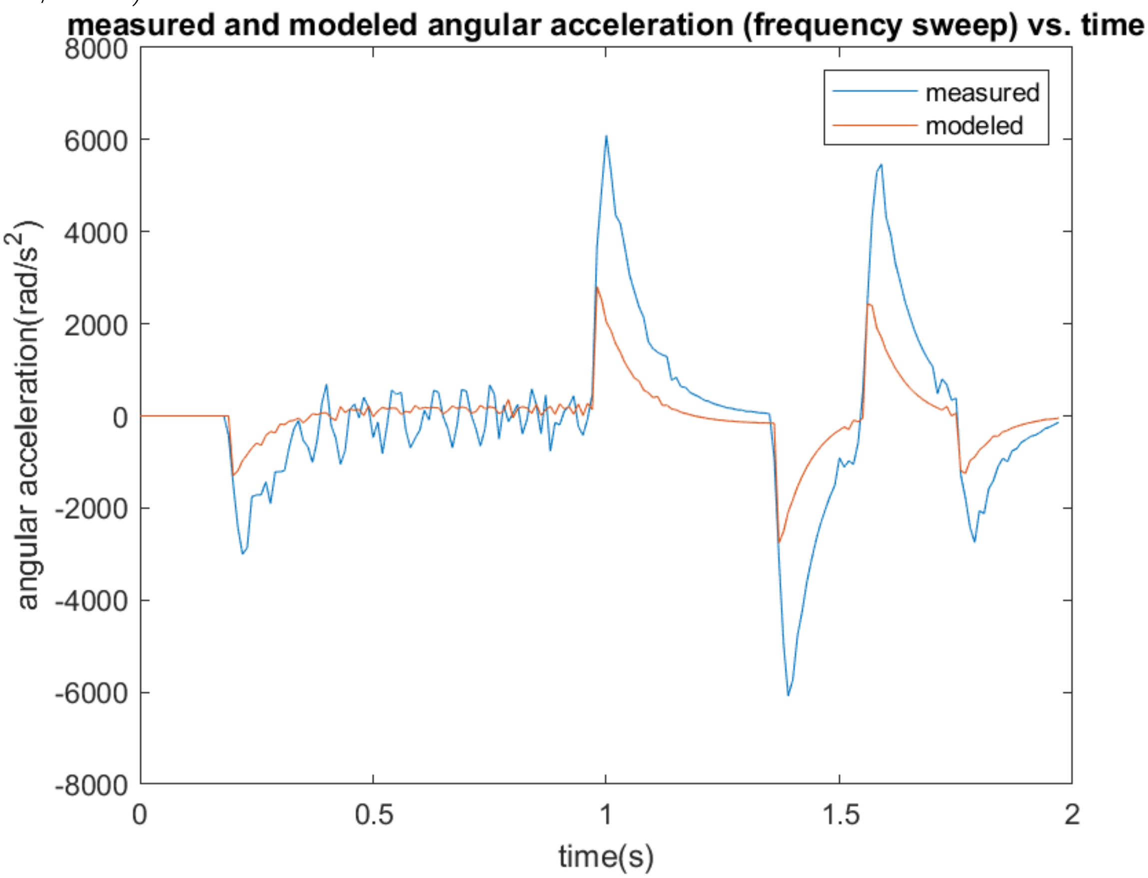
1.0000

6.8891

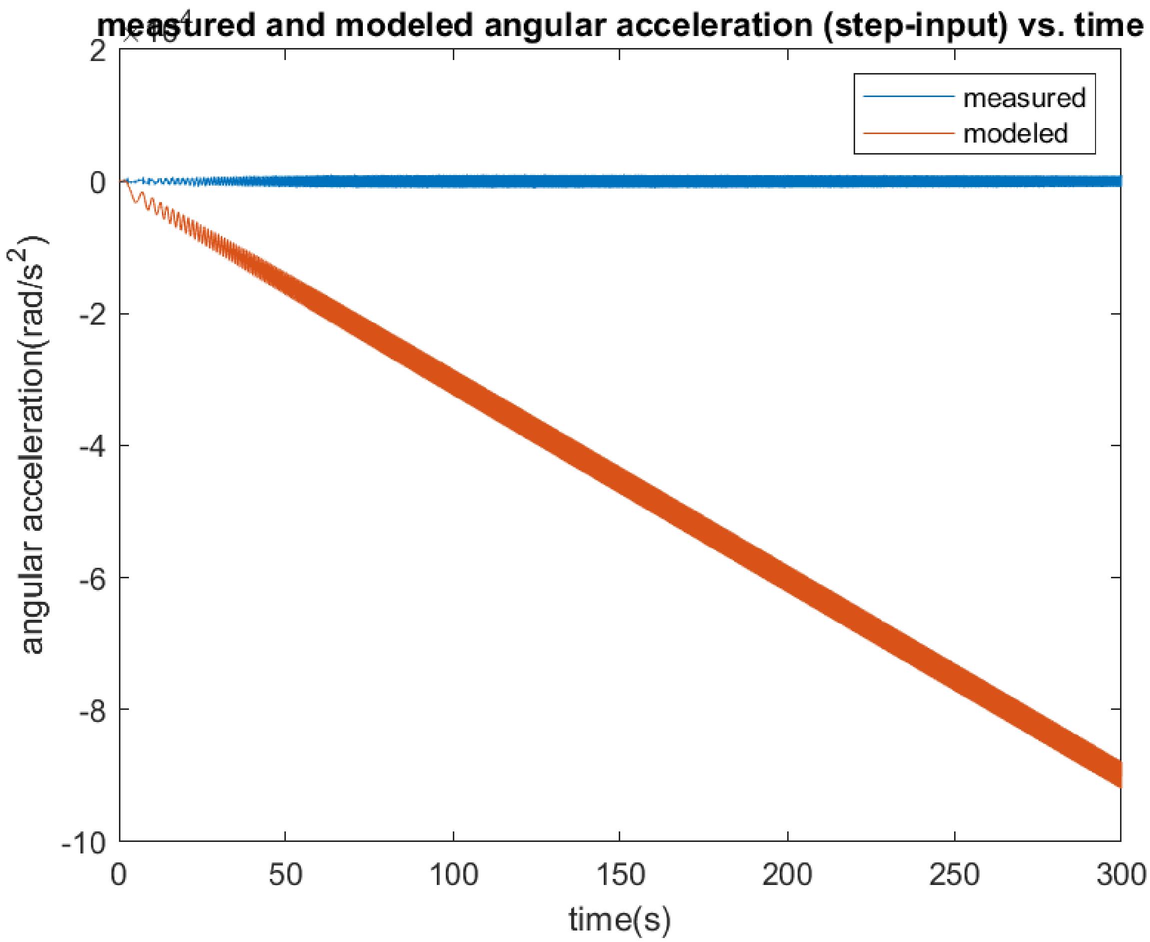
40.8424

304.8865

5. **Validation:** For each input data type, use the other data file as validation data. Use these validation datasets to look at how well your OLS model can predict the motion. Show the validation plots (should be 2 total, 1 from each input file/model) Comment on models seem to be better.



The frequency sweep model is fairly resilient.



The step input model is not resilient.

The frequency sweep model validation using step input data R squared value is:

R_sq_val =

0.3628

The step input model validation using frequency sweep data R squared value is:

R_sq2_val =

2.1612

This R^2 value might explain why the model is performing so poorly.

6. **Collinearity Sample Problem:** Using the quad_roll.mat file on Canvas, you need to perform the three collinearity checks (identical to Problem 4 above). Where does the collinearity exist, and how would you remedy the problem?

Quad.m1cmd and quad.m2cmd are the two motors that induce roll motion (one is right motor, one is left motor). Use the deriv.m function to calculate the roll angular acceleration. Use angular acceleration as your dependent variable (z), and a model structure containing m1cmd, m2cmd, roll_rate, and the bias.

correlation coefficient matrix (quad roll) =

1.0000	0.5645	-0.3481
0.5645	1.0000	0.3127
-0.3481	0.3127	1.0000

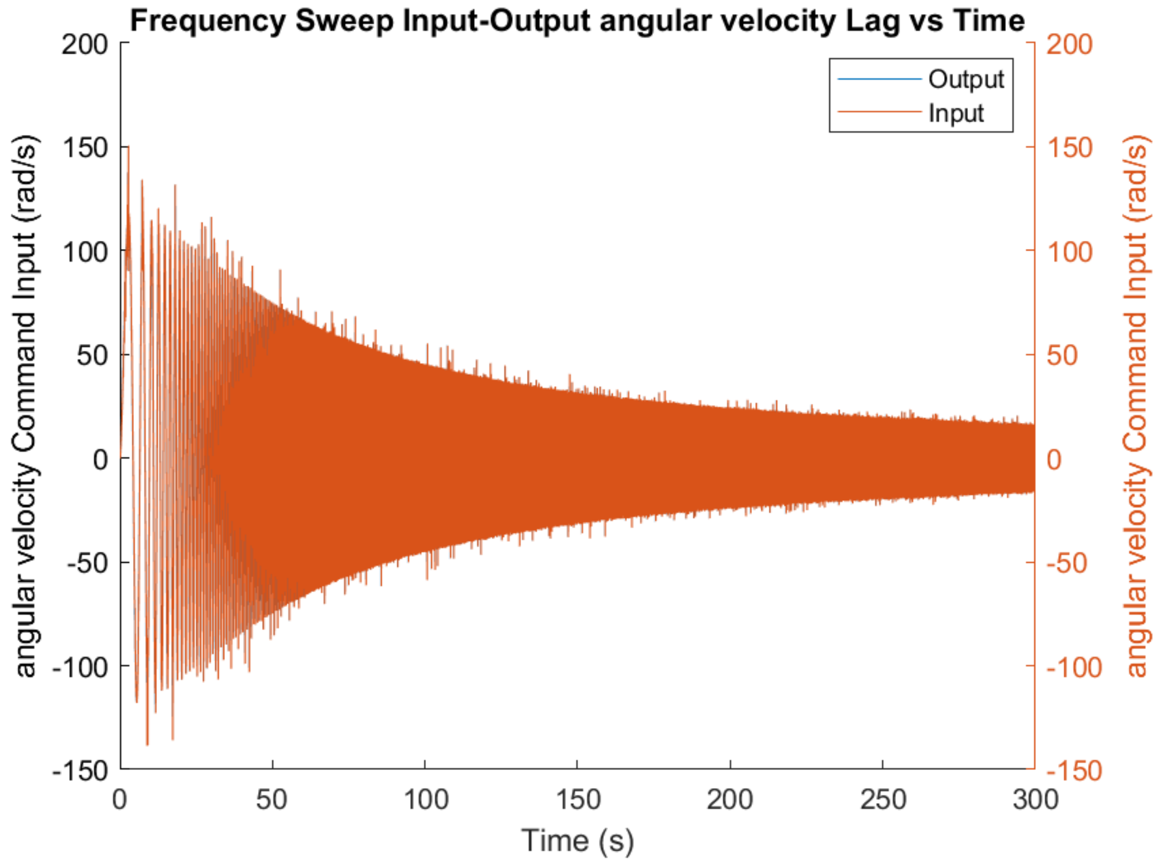
The largest collinearity exist between motor 1 and motor 2. A filter might remedy this problem.

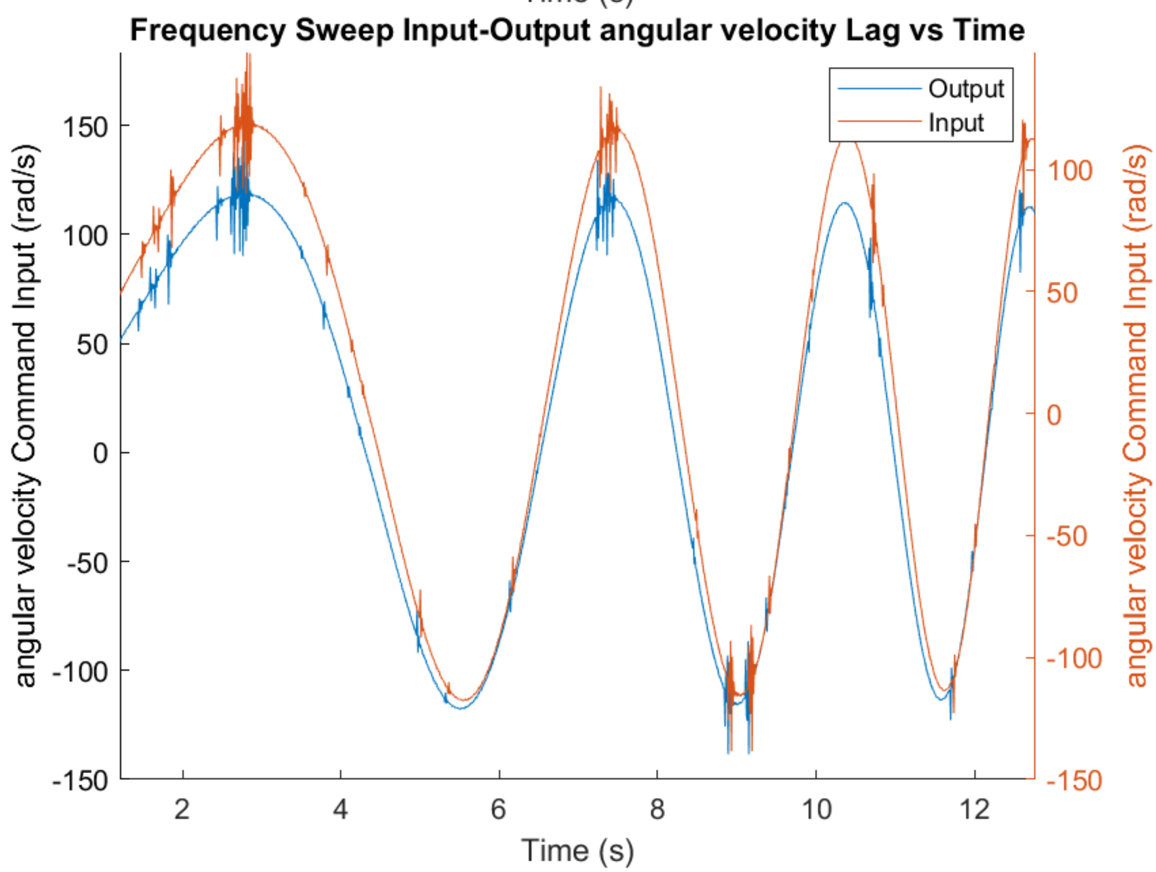
R2 (quad roll) =

0.6237
0.6137
0.5017

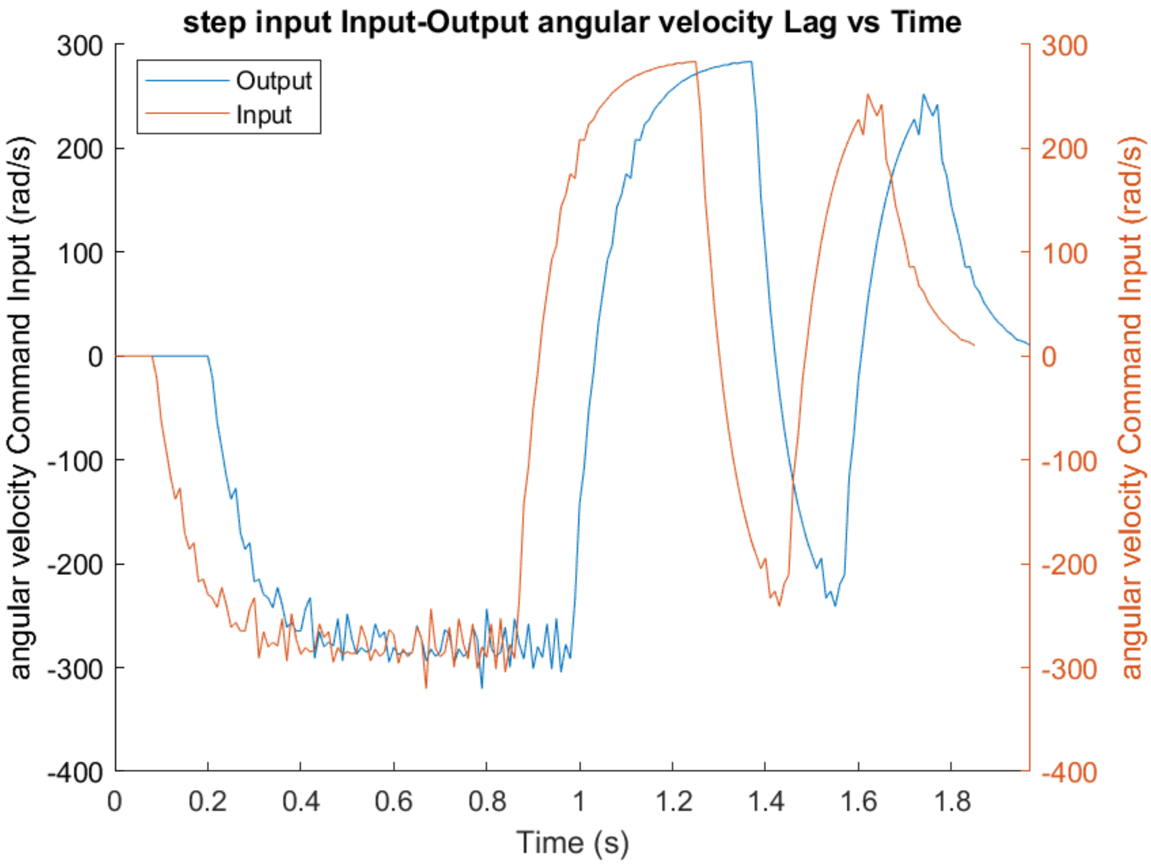
condition number (quad roll)=
1.0000
1.5402
83.1621

7. **Graduate Students Only:** Using the Qube input files, examine the input command and dependent variable (angular acceleration) and perform a crosscorrelation to quantify the time lag between the input and output data. Shift the data by the appropriate amount of "lags." Show a plot of the input and output on a single plot (plotyy is useful for this) **before** and **after** time shifting (2 plots total). Is the time lag constant? Repeat this for the second input file. Is the time lag the same between input types? Why or why not?


Frequency Sweep Input-Output angular velocity Lag vs Time
Output
Input
angular velocity Command Input (rad/s)
angular velocity Command Input (rad/s)
Time (s)
200
150
100
50
0
-50
-100
-150
0
50
100
150
200
250
300


Frequency Sweep Input-Output angular velocity Lag vs Time
Output
Input
angular velocity Command Input (rad/s)
angular velocity Command Input (rad/s)
Time (s)
150
100
50
0
-50
-100
-150
2
4
6
8
10
12

(Zoomed in for visibility)
Time lag constant(frequency sweep) = 4



Time lag constant(step input) = 12

The time lag is constant but both models have a different time lag associated to them.