ME 4232: Fluid Power Control Laboratory
University of Minnesota
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Lab. 16: System Identification

Objective

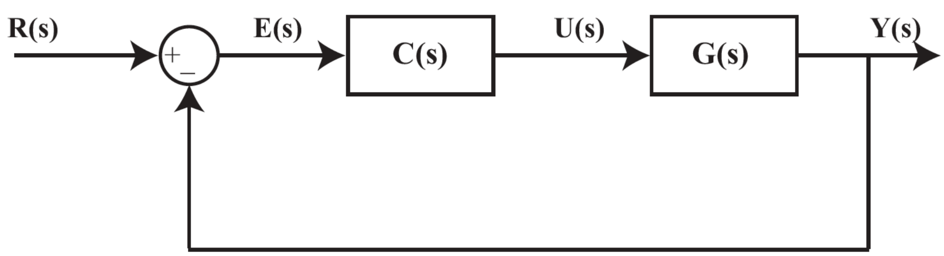
In this lab, you will apply the time domain method and the frequency response method to identify an unknown system.

Preliminaries

In this lab, you will first create an "unknown" system given in the figure below. Where,

- *G(s)* is the Electro-hydraulic actuator system that you identified in Lab 15
- *U(s)* is the control input to the system (1 unit of *u(t)* is equivalent to 1V at the servo valve command)
- *Y(s)* is the position of the actuator **[Adjust your calibration for the linear system so that y = 0 when the actuator is mid stroke]**
- *R(s)* is the exogenous command input.

Typically, *R(s)* is the desired command input which the output *Y(s)* is supposed to follow closely. The "summer" and the controller C(s) form the control system that you need to implement.



Choose C(s) to be a constant i.e., K_p and set it to a small enough value so that a step input of 5cm (or 2in) does not saturate the actuator. (You can figure this out from your previous modeling effort). Make sure that the system is closed loop stable.

You will identify the closed loop transfer function $G_c(s)$, where $G_c(s) = Y(s)/R(s)$. It may be helpful to make Gc(s) a subsystem so that you can forget what is inside it!

Pre-lab exercises (Due at the beginning of the lab)

Given the general transfer function, $G_c(s) = \frac{K_0 a}{s + a}$

Derive the expressions for the following,

1. The step response in the time domain i.e., find y(t) given that $Y(s) = G_c(s)\frac{r}{s}$
2. The impulse response in the time domain i.e., find y(t) given that $Y(s) = G_c(s) \cdot 1$
3. The magnitude of the frequency response of the transfer function: i.e., $|G_c(j\omega)|$

Procedure

Time domain identification

Step response

- Apply a step input to $R(s)$ and record the response $Y(s)$. You should make sure that the valve command input is not saturated.

- Determine the form of $G_c(s)$ i.e., the order of the system.

- Based on the step response and the expressions derived in your pre-lab exercise, determine the coefficients in the transfer function of $G_c(s)$

- You should use different magnitudes for the step input and find the coefficients from the slopes of two relevant straight lines. Least square methods can be used to find the slopes.

Impulse response

Based on your pre-lab exercise, it can be seen that, the impulse response can directly be used to determine the coefficients of the closed loop transfer function. However, an impulse cannot be generated physically because it requires an infinite magnitude (but finite area). You can approximate an impulse using pulses of various widths $T > 0$: $\delta_T(t < 0) = 0$, $\delta_T(t \le 0 \le T) = R$ and $\delta_T(T < t) = 0$, and then make $T \rightarrow 0$. Start with a value of **R = 2 in (or 5cm) and T = 0.25s**. Then gradually decrease the value of T. One can increase R such that the impulse area is the same. However, increasing R beyond 2 [in] may saturate the valve command. Because the system is linear, you can instead, scale the output y(t) such that it corresponds to the same equivalent impulse area.

Plot the appropriate scaled responses to the approximate impulses $\delta_T(t)$ with $T = 0.25$, $T = 0.5$, $T = 1$, *etc....* with impulse area of 0.5in-sec (or 1.25cm-sec). Compare these plots to the theoretical impulse response of the system and comment on the accuracy of the different cases.

Note that each approximate impulse a combination of a step and a delayed reversed step. Can you compute the response?

Frequency domain identification

Chirp signal

Apply a 100 sec. “chirp” signal with initial frequency of 0.001Hz and terminal frequency of 2Hz as $r(t)$. (The frequency range may have to be modified depending on the response of the initial run to zoom into the “interesting” portion). Your TA will show you how to generate the signal. Make sure you understand how this is done. Record both $r(t)$ and $y(t)$.

The envelope of the magnitude plot indicates the frequency response of the system at the various frequencies. Assume that the system is first order and has a pole located at $s = -a$, i.e.

$$G_c(s) = \frac{K_0 a}{s + a}$$

Calculate $|G_c(ja)|$ and $|G_c(j0)|$ from the expression for $|G_c(j\omega)|$ that you obtained in the pre-lab exercise. From this calculation and your chirp response, determine what a and $K0$ are. (Be careful with units of frequency - *Hz* or *rad/s*).

Sinusoidal signal

Apply sinusoidal inputs of various frequencies, and record the output. Use frequencies (rad/s): *0.2a, 0.5a, a, 1.5a, 2a* where "*a*" is the magnitude of the pole location found from the chirp response method. Plot the amplitude gain (output amplitude/input amplitude) in *dB* (i.e. *20*log(gain)*) and the phase (in degrees) against log of frequency (in rad/s).

Estimate the "break" frequency from your frequency response plot. The "break" frequency is the frequency at which straight lines would intersect when they are used to approximate the frequency response plot when plotted using the log-log scale (as in your case). Here, it is also when the gain has decreased by to 3dB from the DC gain. From the estimate of the break frequency, estimate the transfer function $G_c(s)$ (for a first order system, the break frequency, in rad/s, is also your pole location.)

Unwrapping $G_c(s)$ to find G(s)

In the previous 2 parts, you identified $G_c(s)$ using various methods. Determine what $G_c(s)$ is in terms of $G(s)$ and K_p. Solve for $G(s)$ in terms of $G_c(s)$ and K_p. Does this agree with your open loop estimation of $G(s)$ from Lab. 15?

Report

The report should document in detail the identification procedure using various methods. Please make sure to include the following. Additional comments and discussions are encouraged.

- Plot of the step response for one case. (*y* and *r* to be shown)
- The derivations needed in the identification of the various closed loop parameters using the step response method.
- Application of the derivation results to find ***"a"*** and ***"K0".*** Include the graphs with the appropriate straight-lines from which you derive these results.
- Derivation of impulse response
- Side-by-side plots showing the impulse responses (a) experimental (b) ideal result (c) theoretical result of approximate impulse response
- The derivations needed in the identification of the various closed loop parameters using the frequency response method.
- Plot of chirp signal and response on the same figure
- Application of the derivation results for the case shown in the plot to find ***"a"*** and ***"K0"***
- Plot of the sinusoidal response for one case. (*y* and *r* to be shown)
- Table of response magnitudes at each of the sinusoidal magnitudes tested.
- Bode plot zoomed in around corner frequency. Include markers showing the sinusoidal frequencies you used.
- Show how you got ***"a"*** and ***"K0"*** from the previous information using the frequency domain method.
- Unwrapping: derive the close loop transfer function (If you have not done it already for understanding the stability case) and then estimate the value of K in the open loop transfer function $G(s) = K/s$ and see how well it compares to Lab 15.