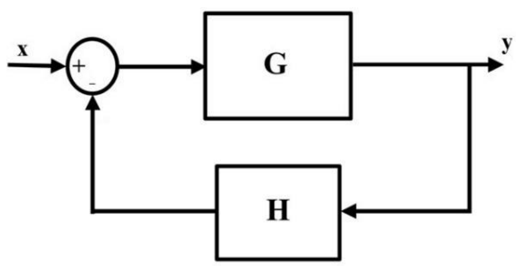
Cairo University
Faculty of Engineering

EECE 3^{rd} year

Control Lab

I-Bode Plot

In this problem, It is required to investigate the time domain and frequency domain characteristics of a continuous time block placed in a feedback configuration using $MATLAB$. The model is as follows:



Where $G(S) = \frac{1}{S(S+1)}$ & $H(S) = 1$ (unity-feedback system)

1) Use $tf()$ or $zpk()$ commands to define $G(S)$ & $H(S)$.
2) Use the $step()$ command to plot the output of $G(S)$ block i.e $step(G)$, This would show the response of the block $G(S)$ for a unit step input, Is it stable? Is this expected?
3) Use $feedback()$ command to model the closed loop transfer function, Compare it to the formula $\frac{G}{1+GH}$. Compare it with hand analysis.
4) Use the $step()$ command to plot the output of the closed loop, Is it stable? Is this expected or not? Are there some damped oscillations?
5) By using $pzmap()$ command, What are the locations of the poles of the closed loop transfer function? compare it with your hand analysis. Does this agree with your result in 4)? Do the locations of closed loop poles agree with your answer to "*Are there some damped oscillations?*"
6) On the step response curve of the closed loop, right click on the curve -> characteristics, mark each of peak response, settling time, steady state. Compare with hand analysis
7) What is the value of e_{ss} to a unit step input? Does this agree with the type of the system?
8) Plot the ramp response of the closed loop by applying the command $step(< Closed\_Loop >.* \frac{1}{S})$ and compare it with the ramp input itself $step(1/S)$, Draw the two curves together using $hold\ on$ command in between them, Zoom in at $t = 700\ sec$ for example, what is the e_{ss}? Compare it with hand analysis [$e_{ss_{ramp}} = \frac{1}{K_v}, K_v = \lim_{S \to 0} S.GH(S)$]
9) Plot the frequency response of the system using $margin()$ command, what is $\omega_{gc}, \omega_{pc}, PM, GM$, sketch bode plot yourself and compare your results with $margin()$ command.

II- State Space Representation

In this problem, It is required to investigate the properties of the system described by the following state and output equations using $MATLAB$:

$$\begin{bmatrix} \dot{x_1}(t) \\ \dot{x_2}(t) \end{bmatrix} = \begin{bmatrix} 0 & 1 \\ -6 & -5 \end{bmatrix} \begin{bmatrix} x_1(t) \\ x_2(t) \end{bmatrix} + \begin{bmatrix} 0 \\ 1 \end{bmatrix} u(t) \qquad y = \begin{bmatrix} 1 & 0 \end{bmatrix} \begin{bmatrix} x_1(t) \\ x_2(t) \end{bmatrix}$$

1) Using hand analysis, Find the Transfer Function (Note that it is in controllable form)
2) Using the definition $syms\ s$ to define s as a variable, use $MATLAB$ to find the Transfer Function from the states and output matrices. First define A, B, C, D matrices in $MATLAB$ then use $inv()$ function to get the inverse of a matrix {$[\quad]^{-1}$} and $eye(n)$ to generate an I matrix of size $(n \times n)$, Compare with the result in 1). Check again with $[num, denum] = ss2tf(A, B, C, D)$
3) Use $MATLAB$ to find the state transition matrix $\Phi(t)$, you may get $\Phi(s)$ first using $[sI - A]^{-1}$ then use $MATLAB$ command $ilaplace()$ to get its inverse Laplace i.e. $\Phi(t)$.
   Check that $\Phi(0) = I$
4) Verify that $\dot{\Phi}(t) = A\Phi(t)$, You can get the derivative of a function with respect to an independent variable by using the command $diff(function\_name, independent\_variable)$
5) Use $MATLAB$ to Check Controllability and Observability of this SSR, Are the results expected?
6) By knowing that the states initial conditions are $\begin{bmatrix} x_1(0) \\ x_2(0) \end{bmatrix} = \begin{bmatrix} 0 \\ 1 \end{bmatrix}$,Use $MATLAB$ to Find the unforced (Homogeneous) solution of the states, then find the unforced response $y(t)$.
7) If the initial states are as in 6) find using $MATLAB$ the states solution and the response to unit step input, you can make use of the fact that Convolution in time domain is mapped to multiplication in frequency domain. i.e. $x_{forced} = x_{unforced} + \mathcal{L}^{-1}\{(sI - A)^{-1}BU(s)\}$. Then use x_{forced} to get y_{forced}.
8) If the system is controllable, It is required to use the concept of state feedback to change some transient parameters for the system. First use command $step()$ to observe the step response for the TF found in parts 1) & 2) .. then it is required to make the closed loop has a settling time of 1 sec and $\zeta = 0.7$, Use Hand analysis to find the K matrix by constructing the new matrix $A_c = A - BK$ where $K = [K_1 \ \ K_2]$ that meets the required specs. Then check your answer by running this piece of code with your variables :

```
Ac = A-B*K
[num_2 denum_2] = ss2tf(Ac,B,C,D)
TF_state_feedback = tf(num_2,denum_2)
step(TF_state_feedback)
```

   what is the value of settling time? Overshoot?