Bonus exercise 2 MM 2021/2022

February 21, 2022

Instructions

Use the `bonus2_2021_2022.m` file as a template. Do not use a livescript. Implement the tasks below in Matlab. Give comments where needed. This is an individual assignment. The assignments should be uploaded as a single .m file and not be compressed to facilitate automatic plagiarism checks. You have to upload your solution before 16:00h (Maastricht time) on March 15, 2022 through the student portal. Start early and don't postpone. This is an individual graded assignment. What you submit should be your work alone and by submitting it you testify that this is indeed the case. (No copying code. Not from the internet, not from others, etc. It also means not working on it with others). You are not allowed to use any toolboxes (even not the control systems toolbox) unless it is explicitly mentioned in that specific question that you may. Do not include personal information like your name or student ID in the file that you hand in because of sending it for a plagiarism check.

Challenge 1

a)

Suppose we have a signal sampled at $f_s = 300$Hz and we want to build a discrete-time filter, to filter out the powerline interference in the US (60Hz component) and its 120Hz harmonic (just an integer multiple of that frequency). Find the numerator and denominator polynomials for each of the two transfer functions that act as notch filters for each of these frequencies. Then combine them into a single transfer function. Ensure that the poles are at 95% between the origin and the zeros. Enter the combined transfer function in matlab as a *discrete-time* transfer function system `sys1`. For this sole purpose in this particular question you are allowed to use the `tf` function).

Some hints:

1. Test the two separate transfer functions first. When you are sure they are good, then combine them.
2. The output must be real for real inputs, but tiny numerical errors might occur. Don't worry, but make sure the outputs are real.
3. In discrete-time the frequencies do not 'live' on the imaginary axis, but on the unit circle in the complex plane, where 0 radians corresponds to 0Hz and 2π radians corresponds to the sampling frequency f_s Hz.

4. There should be two poles and two zeros for each of the separate transfer functions, hence four poles and four zeros for the combined transfer function.

5. The zeros are on the unit circle.

6. See lecture materials and the course notes.

b)
Plot the magnitude response of this discrete-time filter from 0 Hz to f_s Hz, as well as a pole-zero plot, starting from the following template code:

```
%% Challenge 1b
% Plot the magnitude response (bode magnitude plot)
% first compute the frequency response
omega=linspace(0,2*pi,1000); % frequencies in radians with 1000 data points
H2 %frequency response
% Plot the magnitude response (absolute value of the frequency response)
figure(4);
% ==> your code here
xlabel('frequency (Hz)');
title('Magnitude response Challenge 1b')

% Make a pole-zero plot
figure;
% plot unit circle
tmpx=real(exp(omega*1i));
tmpy=imag(exp(omega*1i));
plot(tmpx,tmpy,'--k');
% plot real axis
hold on
plot(linspace(-1.1,1.1,100),zeros(1,100),'k:');
% plot imaginary axis
plot(zeros(1,100),linspace(-1.1,1.1,100),'k:');
% plot poles with an x
% plot zeros with an o
xlabel('real axis')
ylabel('imaginary axis')
axis square
title('Pole-zero plot Challenge 1b')
```

In the file `data_MM_bonus2_challenge1.mat` you will find a 300Hz sampled dataset `u`.

c)
Load the data and plot the time-domain and frequency-domain representation of the signal. You must start from the code below and modify it (pay attention to the xlabels):

```
figure;
subplot(3,1,1)
% do some plotting
title ('Time domain inout');
xlabel('time (s)') % also make sure you actually have seconds that you show
subplot(3,1,2)
plot((0:length(u)-1)*(fs/length(u)),abs(fft(u))); % magnitude spectrum
title('Magnitude spectrum input');
xlabel('write the meaning and units here')
subplot(3,1,3)
```

```
% todo: add the phase spectum
title('Phase spectrum input');
xlabel('write the meaning and units here')
ylabel('write the meaning and units here')
```

d)

Simulate your combined transfer function using the provided input. Show the magnitude spectrum (Bode magnitude plot) of the input and simulated output superimposed in a single figure, using the following template code:

```
figure;
plot((0:length(u)-1)*(fs/length(u)),abs(fft(u))); % magnitude spectrum input
hold on
% todo: magnitude spectrum output
title('Magnitude spectrum');
xlabel('write the meaning and units here')
```

Relate what you are seeing here with the frequency response and the pole-zero plot and explain what you are seeing from a perspective of the poles, zeros, frequency response and the magnitude spectrum of the original signal. Put this in the comments of the submitted .m file.

Challenge 2

Given the linear system and sampling interval

```
T=0.01; % sampling interval
A=[-1 2 -3;-2 0 -1;2 1 -1]; % System matrix
B=[1; 0; -2]; % input matrix
C=[0 0 2]; % output matrix
D=0; % direct feedthrough
```

and a sampled input signal

```
t=0:T:5-T; %create time vector
u=linspace(-1,1,length(t))+sin(2*t); % sampled time series
```

a)

Find the discrete time equivalent system. Provide Φ and Γ.

b)

Simulate the continuous time system using input $u(t)$ with zero-order-hold (see documentation of `lsim`, which you are free to use) and capture output and state trajectory. Also simulate the discrete time equivalent system with the same inputs. Plot the following in a single figure:

- The output of the continuous-time system in blue
- The output of the equivalent discrete-time system in dashed cyan
- All states of the continuous-time system in red, with different markers for each state
- All states of the discrete-time system in dashed green with different markers for each state

Plot all of this superimposed and make sure to provide a legend.