Group 33 Design Assignment

Course: 5SMB0 System Identification 2024/2025

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# Understanding saturation and Butterworth filter

Bode diagram of F(q) can be represented in the following:

A diagram of a function

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The cut off frequency at -3dB is determined to be 0.719π (x = 0.72 )

In order to determine M we need to design a signal r(t) to drive the system into saturation. This signal should be predictable and trigger the saturation of filter (-M and +M).

A ramp signal is useful here to gradually increase the intensity over time to observe when the saturation filter comes into effect.

A graph with a line

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Based on the observed response we can estimate M to be 1.80

It’s important to know the value M, because the saturation filter blocks signals above and below it, leading to stability within an operating range. This might be due to a physical limiation of actuaterrs, therefore knowing this limit will help us avoid damaging the system through exessive signal.

# Nonparametric identification

## Defining r(t) as a multi sine wave

A multi sine wave covers a wide range of frequencies whitin the system passband. It can also offer a linear signal, in the operating range of the system, without going beyond the given domain.

where:

* AkA\_kAk​ is the amplitude of the kkk-th sine component.
* fkf\_kfk​ are 100 logarithmically spaced frequencies within the passband of the Butterworth filter.
* ϕk\phi\_kϕk​ are random phase shifts to ensure good time-domain properties.
* N=1500N = 1500N=1500 samples.

The FRF could be displayed as below:

A diagram of a bode plot

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In higer frequencies, we observe a random fluctutating response which might indicated higher frequencies are not captured by the system model (G).The peak frequencies show that the input signal matched the natural resonance of the system.

To estimate the noise spectrum we could benefit from the following equasion:

Where:

* is Power spectral density (PSD) of the output y(t)
* is Cross-power spectral density (CPSD) of input u(t) and output y(t)
* is Power spectral density (PSD) of the input u(t)

Using the cpsd matlab function, we can get an estimation of noise spectrum and plot this figure:

A graph showing a number of noise

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This plot shows that with increase frequency, the noise increases which indicate unmodeled dynamics or sensor noise. Secondly, …

# Experiment design

There are a number of signal types we can exlpore

Here we’re usign a multi sine wave with 3000 points and 100 frequencies within the passband.

A graph showing a multi-sine signal

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The reason we chose multi sign and not for instance a PRBS, was that multi sine allow us to excite the system in multiple frequencies at the same time. In the next part we use this signal to identify G0(q)

# Parametric identification and validationsing

Based on Lecture 4, we use all types of model and use AIC to validate which model is better.

1. Comparing different models

| Model Structure type | Abbr. | AICa |
| --- | --- | --- |
| AutoRegressive with eXogenous input | ARX | 2.92 |
| AutoRegressive Moving Average with eXogenous input | ARMAX | 2.17 |
| Output-Error | OE | 2.52 |
| Box-Jenkins | BJ | 2.23 |

1. Akaike Information Criterion

The lowest AIC according to table 1 belongs to ARMAX method. So we choose this model with the following structure:

- \( A(q) \) is the \*\*autoregressive (AR) polynomial\*\*, modeling how past outputs affect the current output.

- \( B(q) \) is the \*\*input polynomial\*\*, modeling how past inputs influence the output.

- \( C(q) \) is the \*\*moving average (MA) polynomial\*\*, modeling the effect of past noise terms.

- \( q^{-1} \) is the \*\*shift operator\*\*, meaning \( q^{-1}y(t) = y(t-1) \).

- \( u(t) \) is the \*\*input signal\*\*.

- \( y(t) \) is the \*\*output signal\*\*.

- \( e(t) \) is the \*\*white noise\*\*.

To see how the chosed model perfoms we plot the residue (difference in model output against actual output). Here’s the result:

A graph of a graph of a certain number of data

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As shown in the figure, both autocorrelation and x correlation graphs shows a normal random distrbution of residues, which means the ARMAX model is capturing the dynamics of G

Model orders are :

* na = 2
* nb = 2
* nc = 2
* nk = 1

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