Lab Assignment A

Estimation

Examination: Submitted report in CANVAS.

1 Introduction

In this lab assignment different estimation techniques to recover system states from measurement will be explored and compared. The main aim is to study the Kalman Filter (KF) and the Extended Kalman Filter (EKF).

If you have not been working with the double tank system before and do not have a model of it from a prior course, then you should read and perform the work which is indicated in *R7014E Double tank system.pdf*.

In case you run into trouble and the trouble shooting is not helpful, please contact us right away!

2 Problem description

Your task is to design and implement state estimators which are able to recover all the states of the system, but most importantly the level h_1. For this estimation you are not allowed to make use of the measurement in h_1, but the measurements from u and h_2 should be used. The implementation shall be done in Simulink. Any blocks are allowed

Note: The system does not need to operate in closed loop. You do not need to design a controller.

2.1 Assumption

- Measurements: level measurement of the lower tank h_2
- Control signal: pump voltage u
- The pump can be represented by a static map $f(u)$
- The sensor calibration map $g(h)$ is only needed to map the voltage from the sensor to a level value in centimeters

2.2 Estimators, required and optional

You will design several observers and compare them. The design and testing will be done for the following three observers:

- stationary KF (either discrete or continuous)
- non-stationary discrete time KF

- discrete time EKF (optional)

Note: We will not use the direct term implementation in this lab.

2.3 Important aspects

- The variance measures (intensity) can be derived from data of the process. Be aware of obscure behaviour and discard it if necessary.
- It should also be noted that the performance of the estimators should be such that they could be used for closed loop control, where the settling time of the closed loop should be less than 80 seconds.
- The implementation of the non-stationary observers is a challenge, since you will have to implement matrix multiplications and store matrixes between calculation steps.

3 Creation of the development environment

The development environment should enable you to develop and test your estimators before you run it with the real-life tank process.

Task 1 *Implement the linear and non-linear model of the tank process in Simulink. You need to add noise to the measurement values. You can do that with assumed parameters in the model.*

Task 2 *Design a startup sequence or initialization routine such that you are able to start the estimator in a proper way. Assume, the estimator is a subsystem now that is getting u and h_2 as input and provides $\hat{h}_1$ and $\hat{h}_2$ as output.*

While any stationary estimator can be easily implemented in Simulink, estimators which operate non-stationary or have varying characteristics are more difficult to implement. Block which are freely programmable might simplify the implementation step. The next task shows you an example of that.

Task 3 *Analyze the `embeddedM_example.slx`, which is provided. Implement it in your estimator block as you see fit.*

Note: You may also use other approaches like S-functions or direct implementation in Simulink.

Now the development environment is ready for designing and test of your estimators.

4 Estimator design

Before we can design dscrete time estimators we need to have a discrete time model.

Task 4 *Derive a discrete time state space representation for your process model that reflects the system behaviour well.*

An alternative approach is of course to design a continuous time estimator and then discretize for implementation.

for each of the three estimators perform the following tasks:

Task 5 *Design the estimator according to the textbook or lecture notes*

Task 6 *Implement the estimator in the development environment*

Task 7 *Test the estimator in the development environment*

Now you have design all the three estimators and tested them.

5 Comparison and experiments in the development environment

The key performance indicator for the estimators is the estimation error. There are three important properties of the estimation error:

1. Convergence time
2. root mean square error

In order to explore the performance the following experiments need to be performed:

1. Estimation during normal operation at the operating point.
2. Estimation at 12 cm in both lower and upper tank.
3. Estimation in the presence of a leakage flow.

The above properties should be compared between the different estimators and discussed in the report. You should also conclude which estimator performs best and why.

Task 8 *Compare the estimators using the above performance indicator. Do also compare the kalman gain over time for the estimators.*

6 Run the estimators on the real-life tank system

Now that the estimators are implemented and tested, they can be run on the real life tank system.

Task 9 *Copy all the estimators to a new Simulink blockdiagram and run them in parallel with the real-life tank system, according to the above experiments.*

Task 10 *Compare the estimators using the above performance indicator. Discuss which estimator performs best.*