Control Systems II - Laboratory 1

March 14, 2018

1. System description

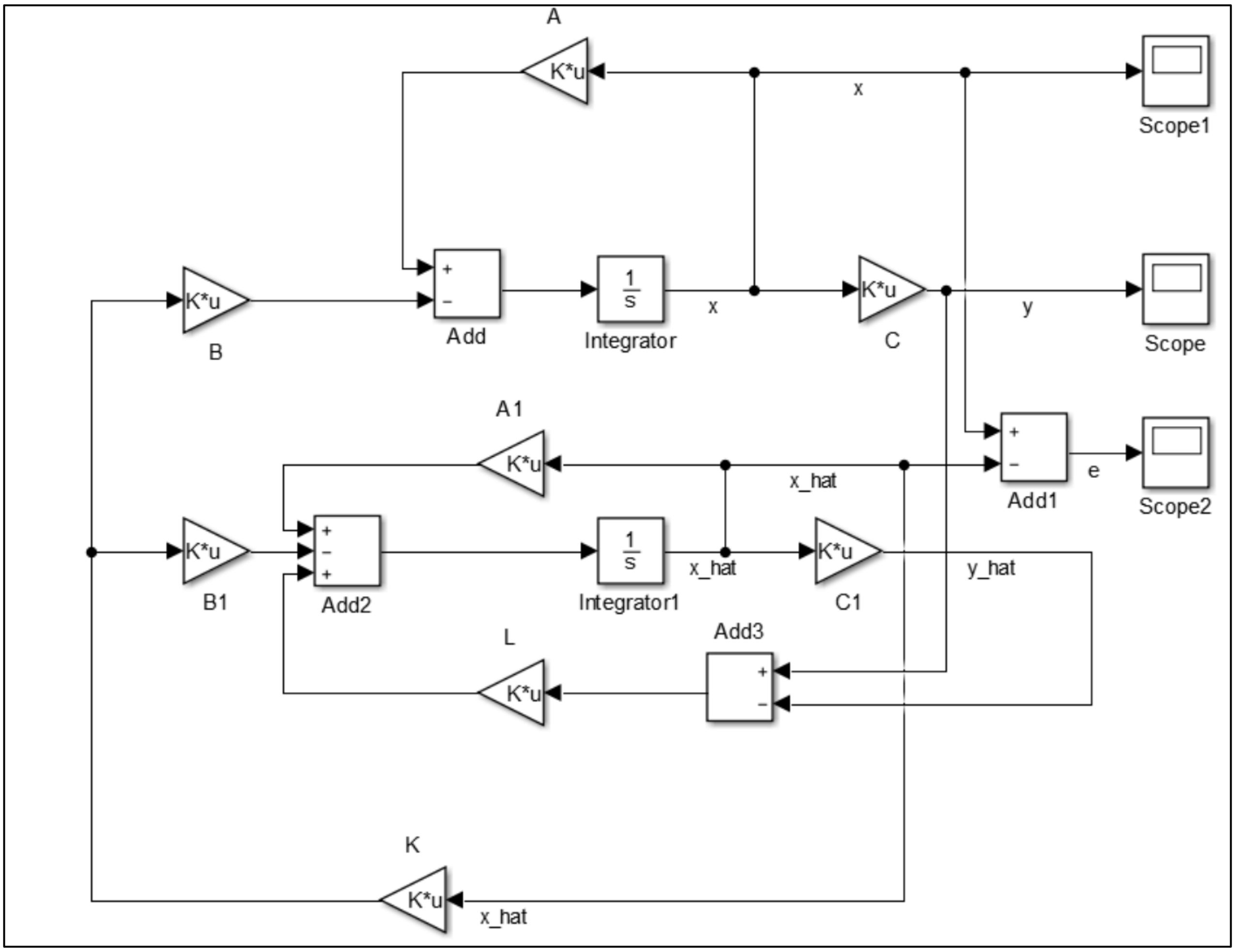

Figure 1 - Dynamic Output Compensator Design

Figure 1 shows the simulation in Simulink of a closed loop system (longitudinal dynamics of an aircraft) with a dynamic output compensator. The system state space matrices are *A*, *B* and *C*. The observer and compensator matrices are *A1*, *B1*, *C1*, *L* and *K*. The gain matrices *L* and *K* were calculated in MATLAB using the `acker()` command which uses the Ackermann formula to compute the matrices. This formula runs for the following poles: [-3, -1+j, -1-j, -2] (closed-loop system poles) and [-2, -1.5+1.5j, -1.5-1.5j, -1] (observer error poles). The code written and final compensator and observer gain matrices are shown below.

Gain Matrix *K*

$$K = [0.0119 \quad 0.0042 \quad -0.6155 \quad -0.0880]$$

Gain Matrix *L*

$$L = \begin{bmatrix} 345.5359 \\ -785.2217 \\ -0.2450 \\ -2.8664 \end{bmatrix}$$

MATLAB code:

```
A5 = [-0.045, 0.036, -32, -2; -0.4, -3, -0.3, 250; 0, 0, 0, 1; 0.002, -0.04, 0.001, -3.2]
B5 = [0;-30;0;-10]
C5 = [0, 0, 1, 0]
P5 = [-3, -1+1j, -1-1j, -2]
Po = [-2, -1.5+1.5j, -1.5-1.5j, -1]

A5t = transpose(A5)
C5t = transpose(C5)
L5 = acker(A5t,C5t,Po)'
%out: L5 = 345.5359  ;  -785.2217  ;  -0.2450  ;  -2.8664

K5 = acker(A5,B5,P5)
%out: K5 = 0.0119    0.0042   -0.6155   -0.0880
```

Figure 2 - MATLAB code written

Thomas Hollis (9563426)

2. Simulated time response of close-loop system

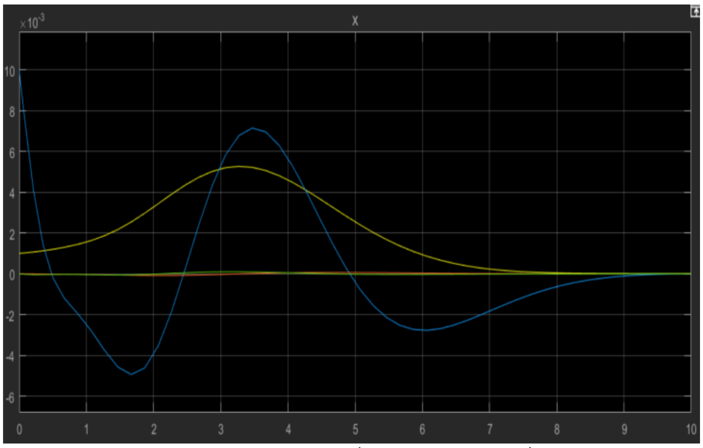

Figure 3 - Scope 1 output (system input)

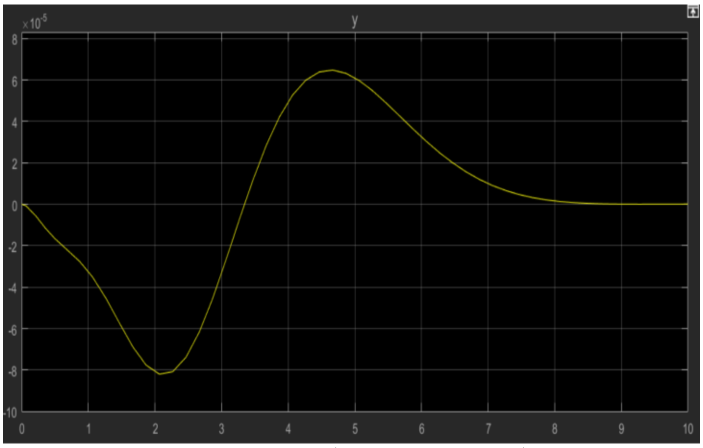

Figure 4 - Scope output (system output)

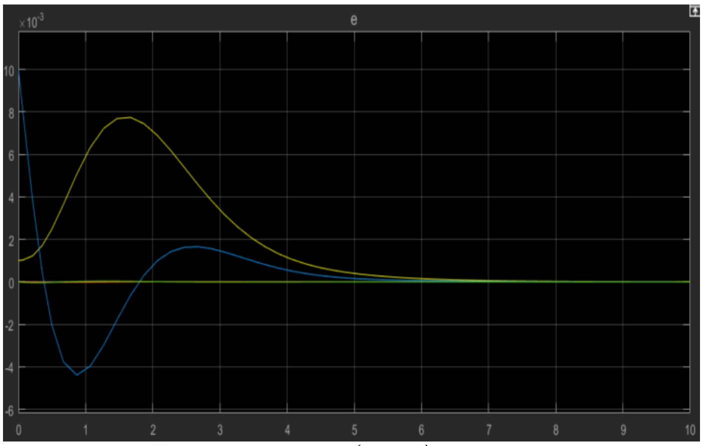

Figure 5 - Scope 2 output (error)

3. Typical performance

Figure 3 (aside) shows the system's closed loop behaviour after the integrator block (before multiplication with the matrix C). This corresponds to the input matrix of the system which fluctuates according to feedback and initial conditions. As shown in figure 3, all values eventually tend to 0. This signal is taken and used to compute the error, as will be discussed later in figure 5.

These simulated values correspond to the expected theoretical output of the system and were verified analytically by hand.

Figure 4 (aside) shows the system's output signal. This signal is indeed heavily influenced by the state space control design because this dynamic output compensator is using the signal output for control. This can clearly be seen as the signal y is taken from the output and fed into the controller as $\hat{y}$. The system here is definitely stable as the output ultimately settles to a plateau (here 0, but can be offset if needed). This is because the poles are in the left-hand plane.

These simulated values were also verified analytically by hand and correspond to the theoretical expected values.

Figure 5 (aside) shows the system's error signal. This signal is the difference between the system input x (shown in figure 3) and the feedback input $\hat{x}$.

Indeed, this shows further evidence of stability as it also reaches a plateau of 0. This suggests that as there is no more error, there is no more compensation to be done so the controller has successfully converged.

The values are also typical as they correspond to the theoretical values calculated by hand.

Overall this system performs as expected.

4. Comments/Analysis on performance

When designing this dynamic feedback control, we used the state estimate rather than the state variable used in full state control design. As a consequence, the settling time in this system is approximately 8 seconds. This is fairly fast but not as fast as the dynamic output compensator in task 4. This is probably due to the complexity of the input parameters and initial conditions.

A faster settling time would be possible but would require more controller power or more optimal control.

The type of performance is a stable one as the controller relies on the output signal to control and stabilise the system. Since all the roots are in the left half of the complex plane, the augmented system is stable. This is the separation principle. Indeed, stability is not necessarily guaranteed for all dynamic output compensator designs for all input conditions.

Thomas Hollis (9563426)