

# LaTeX Lab Report Skeleton

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# 1 10.2 - Optimal Control of Pitch/Travel without Feedback

## 1.1 The continuous model

Answer 10.2.1.1

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Since the task were to control the pitch and travel, the elevation was not a part of the system model. The system's state was therefore described by:

$$\mathbf{x} = [\lambda \quad r \quad p \quad \dot{p}] \quad (1)$$

The dynamic equations for the system was given in the problem description. The following equations were given:

$$\dot{\lambda} = r \quad (2a)$$

$$\dot{r} = -K_2 p, \quad K_2 = \frac{K_p l_a}{J_t} \quad (2b)$$

$$\dot{p} = \dot{p} \quad (2c)$$

$$\ddot{p} = -K_1 K_{pd} \dot{p} - K_1 K_{pp} p + K_1 K_{pp} p_c, \quad K_1 = \frac{K_f l_h}{J_p} \quad (2d)$$

The state-space form of the system therefore becomes:

$$\underbrace{\begin{bmatrix} \dot{\lambda} \\ \dot{r} \\ \dot{p} \\ \ddot{p} \end{bmatrix}}_{\dot{\mathbf{x}}} = \underbrace{\begin{bmatrix} 0 & 1 & 0 & 0 \\ 0 & 0 & -K_2 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & -K_1 K_{pp} & -K_1 K_{pd} \end{bmatrix}}_{\mathbf{A}_c} \mathbf{x} + \underbrace{\begin{bmatrix} 0 \\ 0 \\ 0 \\ K_1 K_{pp} \end{bmatrix}}_{\mathbf{B}_c} \underbrace{p_c}_u \quad (3)$$

## 1.2 The discretized model

Answer 10.2.1.2. Remember to document the calculations.

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### 1.2.1 Discretizing model

Forward Euler method is given by:

$$\mathbf{x}[k+1] = \mathbf{I}\mathbf{x}[k] + T\mathbf{A}_c\mathbf{x}[k] + T\mathbf{B}_c \quad (4)$$

, where  $T$  is the timestep

timestep in the discretization??

Add reference to linsys slides

. Reformulating this, we can write:

$$\mathbf{x}_{k+1} = \underbrace{(\mathbf{I} - T\mathbf{A}_c)}_{\mathbf{A}} \mathbf{x}_k + \underbrace{T\mathbf{B}_c}_{\mathbf{B}} u_k \quad (5)$$

### 1.2.2 Checking stability

The stability condition for eq. (5) is:

$$|1 + T\lambda| \leq 1 \quad (6)$$

, where  $\lambda$  is an eigenvalue of  $\mathbf{A}$  in eq. (5). Using MATLAB we found the eigenvalues of  $\mathbf{A}$  to be ...

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Add Matlab appendix
```

```
find eigenvalues
```

### 1.3 The open loop optimization problem

*How is it formulated?*

### 1.4 The weights of the optimization problem

*Try using the values 0.1, 1 and 10 as weights  $q$ . Plot the manipulated variable and the output. Comment the results with respect to the different weights chosen.*

### 1.5 The objective function

*Furthermore, discuss the objective function (15) (in the lab assignment text) in particular the term  $(\lambda_i - \lambda_f)^2$ . For instance, could any unwanted effects arise from steering the helicopter to  $\lambda = \lambda_f$  with this objective function?*

### 1.6 Experimental results

*Printouts of data from relevant experiments (plots). Discussion and analysis of the results. Answer 10.2.2.7 here.*

### 1.7 MATLAB and Simulink

*Code and diagrams go here*

## **2 10.3 - Optimal Control of Pitch/Travel with Feedback (LQ)**

### **2.1 LQ controller**

*Briefly explain LQ controller. Especially, but not limited to, what is the role of the matrices  $Q$  and  $R$ ? Justify your choice of weights.*

### **2.2 Model Predictive Control**

*Answer 10.3.1.3 here.*

### **2.3 Experimental results**

*Printouts of data from relevant experiments (plots). Discussion and analysis of the results. Answer 10.3.2.5 here.*

### **2.4 MATLAB and Simulink**

*Code and diagrams go here*

### **3 10.4 - Optimal Control of Pitch/Travel and Elevation with Feedback**

#### **3.1 The continuous model**

*Answer 10.4.1.1*

#### **3.2 The discretized model**

*Answer 10.4.1.2*

#### **3.3 Experimental results**

*Printouts of data from relevant experiments (plots). Discussion and analysis of the results. Answer 10.4.2.6 here.*

#### **3.4 Decoupled model**

*Answer 10.4.2.7*

#### **3.5 MATLAB and Simulink**

*Code and diagrams go here*

#### **3.6 Optional exercise**

*Which constraints did you add? What was the results? Plots? Discussion?*

## References