TTK4135 Optimization and Control
Lab Report

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Abstract

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2 Problem Description

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3 Repetition/Introduction to Simulink/QuaRC

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4 Optimal Control of Pitch/Travel without Feedback

4.1 State-space formulation

4.2 Discretization

4.3 Computation of optimal trajectory

An optimal trajectory can be generated by minimizing the cost function

$$\phi = \sum_{i=1}^{N} (\lambda_i - \lambda_f)^2 + q p_{ci}^2 \tag{1}$$

for some scalar weight $q \geq 0$ over the finite horizon of states and inputs

$$z = (x_1\ x_2\ \dots\ x_N\ u_1\ u_2\ \dots\ u_N)^T \tag{2}$$

The discrete-time system dynamics are implemented as equality constraints of the form $A_{\text{eq}} z = B_{\text{eq}}$, where A_{eq} and B_{eq} are given by the left- and right-hand side of the N constraints

$$\begin{aligned} x_1 - Bu_0 &= Ax_0 \\ x_2 - Ax_1 - Bu_1 &= 0 \\ &\vdots \\ x_N - Ax_{N-1} - Bu_{N-1} &= 0 \end{aligned}$$

We would also like to constrain the system state and input to be within a range

$$x^{\min} \leq x_{t+1} \leq x^{\max} \tag{3}$$

$$u^{\min} \leq u_t \leq u^{\max} \tag{4}$$

for $t = 0 \dots N-1$. Applying these constraints to all states and inputs in the solution horizon, we have

$$\begin{bmatrix} I \\ -I \end{bmatrix} z \leq \begin{bmatrix} \{x_{t+1}^{max}\} \\ \{u_t^{max}\} \\ \{x_{t+1}^{min}\} \\ \{u_t^{min}\} \end{bmatrix}_{t=0..N-1} \tag{5}$$

which can be implemented as an inequality constraint of the form $A_{\text{iq}} z \leq B_{\text{iq}}$.

Note that the cost function (1) does not take into consideration that λ_i plus some multiple of 2π describes the same physical orientation of the helicopter. For example, if the reference is 0 and $\lambda_i = 2\pi$, it will be regarded as a large error, even though the helicopter is infact in the desired orientation. A more optimal scheme would take this into consideration.

5 Optimal Control of Pitch/Travel with Feedback (LQ)

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6 Optimal Control of Pitch/Travel and Elevation with and without Feedback

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7 Discussion

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8 Conclusion

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A MATLAB Code

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A.1 plot_constraint.m

```matlab
% Plot a figure with some Latex in the labels
l = linspace(70,170)*pi/180;
a = 0.2;
b = 20;
l_b = 2*pi/3;

e = a*exp(-b*(l-l_b).^2);

l_deg = l*180/pi;
e_deg = e*180/pi;

figure(1)
plot(l_deg,e_deg, 'LineWidth', 2)

handles(1) = xlabel('$\lambda$/degrees');
handles(2) = ylabel('$e$/degrees');
set(handles, 'Interpreter', 'Latex');
```

B Simulink Diagrams

This section should contain your Simulink diagrams.

B.1 A Simulink Diagram

Figure 1 shows a Simulink diagram.

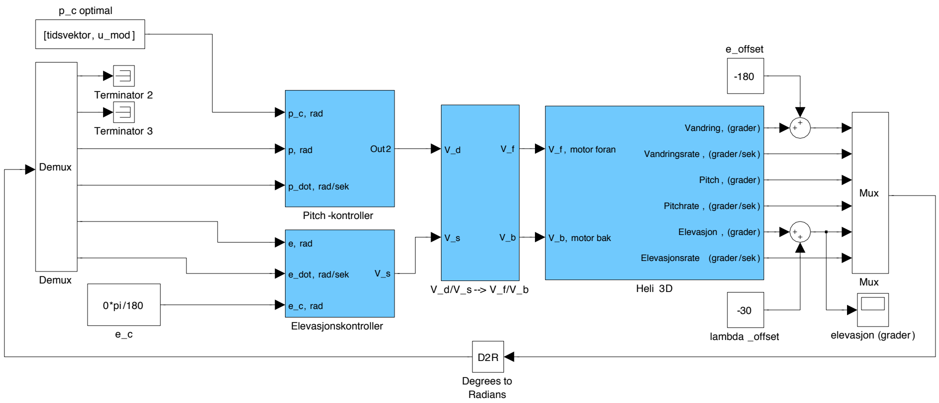

Figure 1: A Simulink diagram.

Bibliography

Nocedal, J. and Wright, S. J. (2006). *Numerical Optimization.* Springer, second edition.