Aalborg University

Model Predictive Control of Batch Production in Livestock Stables

Department of
Control & Automation

Group:
CA-936

Master thesis

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Fredrik Bajers Vej 7
DK-9220 Aalborg East, Denmark
http://www.es.aau.dk

AALBORG UNIVERSITY
STUDENT REPORT

Topic:

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Participants:

Daniel Bähner Andersen
Nicolaj Vinkel Christensen

Supervisors:

Jan Bendtsen
Jesper Mogensen

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Preface

This report covers a Master thesis at Control and Automation at Aalborg university for the Department of Electronic systems. The project is produced by group 17gr936.
The goal of this project is to do model predictive control of batch production in livestock stables

The report starts with a small introduction to the problem, how it is modelled and parameters are estimated. This is followed by the simulation, derivation of the controller and implementation. A discussion about ideas of improvement leads up to the final conclusion.

The reader can find a nomenclature at the beginning of the report which includes acronyms, a symbolic list and a notation list. In the appendix, detailed derivation, an assumption list, relevant measurements used for this project and a complete overview of the test setup can be found.

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Daniel Bähner Andersen
dban13@student.aau.dk

Nicolaj Vinkel Christensen
nvch13@student.aau.dk

Nomenclature

Acronyms

MP	Minimization Problem
KVL	Kirchhoff´s Voltage Law
KCL	Kirchhoff´s Current Law
MPC	Model Predictive Control
NRMSE	Normalized Root Mean Square Error
MNGB	Matlab Nonlinear Grey Box

Symbols

Symbol	**Description**	**Unit**

Glossary of mathematical notation

This section sums up the mathematical notation and terminology used in this report.

Upper and lower bounds of a variable

$$\underline{x} < x < \overline{x} \tag{1}$$

Where $x \in \mathbb{R}$ and $\overline{x}$ and $\underline{x}$ are the upper and lower bounds, respectively.

Intervals

$$[a, b] = \{x \in \mathbb{R} | a \leq x \leq b|\}\underline{x} < x < \overline{x} \tag{2}$$

Where $\overline{x}$ and $\underline{x}$ are the upper and lower bounds, respectively.

Vectors and matrices

Vectors and matrices are noted with bold fonts, such that $\boldsymbol{v}$ is a vector:

$$\boldsymbol{v} = \begin{bmatrix} v_1 \\ v_2 \\ \vdots \\ v_n \end{bmatrix} \in \mathbb{R}^{(n\times 1)} \tag{3}$$

and $\boldsymbol{M}$ is a matrix:

$$\boldsymbol{M} = \begin{bmatrix} m_{11} & m_{12} & \dots & m_{1k} \\ m_{21} & m_{22} & \dots & m_{2k} \\ \vdots & \vdots & \ddots & \vdots \\ m_{n1} & m_{n2} & \dots & m_{nk} \end{bmatrix} \in \mathbb{R}^{(n\times k)} \tag{4}$$

Continues vector variables are noted with $\boldsymbol{v(t)}$ such that:

$$\boldsymbol{v(t)} = \begin{bmatrix} v_1(t) \\ v_2(t) \\ \vdots \\ v_n(t) \end{bmatrix} \in \mathbb{R}^{(n\times 1)} \tag{5}$$

While discrete vector variables are referred to as sequences and noted with $\boldsymbol{v[k]}$, such that:

$$\boldsymbol{v[k]} = \begin{bmatrix} v_1[k] \\ v_2[k] \\ \vdots \\ v_n[k] \end{bmatrix} \in \mathbb{R}^{(n\times 1)} \tag{6}$$

is a sequence, where k is the time step between two entries.

The pseudo inverse of a matrix is noted with $\boldsymbol{M}^{\dagger}$.

Small-signal and operating point values

Small-signals are noted with $\hat{u}$ and the operating point values are noted with $\bar{u}$.

Derivatives

The partial derivative of a function is noted with

$$\frac{\partial f(x,y)}{\partial x} \tag{7}$$

The derivative of a vector by vector is noted with:

$$\frac{\partial \boldsymbol{v}}{\partial \boldsymbol{w}} = \begin{bmatrix} \frac{\partial v_1}{\partial w_1} & \frac{\partial v_1}{\partial w_2} & \cdots & \frac{\partial v_1}{\partial w_n} \\ \frac{\partial v_2}{\partial w_1} & \frac{\partial v_2}{\partial w_2} & \cdots & \frac{\partial v_2}{\partial w_n} \\ \vdots & \vdots & \ddots & \vdots \\ \frac{\partial v_k}{\partial w_1} & \frac{\partial v_k}{\partial w_2} & \cdots & \frac{\partial v_k}{\partial w_n} \end{bmatrix} \tag{8}$$

If the size of vector $\boldsymbol{v}$ and $\boldsymbol{w}$ are the same, the resulting matrix is referred to as a Jacobian.

The time derivative of a function is noted with

$$\dot{f} = \frac{df(t)}{dt} \tag{9}$$

Vector fields

Vector fields are introduced, and represent vector valued functions such that the mapping is the following:

$$\alpha(\boldsymbol{v}) : \mathbb{R}^{(n)} \rightarrow \mathbb{R}^{(n)} : [v_1, v_2, \ldots, v_n] \rightarrow [\alpha(v_1), \alpha(v_2), \ldots, \alpha(v_n)] \tag{10}$$

Contents

1 Introduction

The considerations above lead to the following problem statement:

-

Part I

Analysis

System Description 2

This section gives an introduction to the available test system, including structure and components overview.

2.1 System overview

To develop and test different control methods

Modelling 3

Part II

Control Design

4 Controller

In this chapter the design of the controller is explained, including the control problem, optimality and structure. The chosen control approach is then described and leads up to a section where the implementation is discussed.

5 Control System Implementation

This chapter explains how the controller designed in Chapter *4: Controller* is desired to be implemented.

Part III

Conclusion and verification

Discussion 6

Conclusion 7

Part IV

Appendices

Assumption List A

Number	Assumptions	Section reference
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		

Table A.1. List of assumptions.

Measurements B

B.1 Test

Purpose:

The purpose of this test is to determine

Test equipment:

- The ——- [AAU No: xxxxxx]

Procedure:

The following procedure was —–::

1. .
2. .
3. .

Measuring data:

The measurements data can be found on the attached storage under the path: `CD:/Data/`, a plot of the data is shown in *Figure B.1*.

Results:

Figure B.1. Test

Uncertainties of measurement:

- .

Conclusion:

From this test the

Bibliography

Todo list