# DaNet

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## Content

*This newsletter is dedicated to describe part of a Ph.D. project titled "Embedded Controller Design and Automatic Code Generation for Pig Stable Ventilation Systems". The part described here contains a method to perform system identification in a zone divided livestock building which forms the basis for future zone based climate controllers.*

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# Future Climate Control System for Multizone Livestock Buildings based on System Identification

## Introduction

It is widely recognized that the airspace in livestock buildings is imperfectly mixed – see e.g. (Barber & Ogilvie 1982 and 1984, Moor and Berckmans 1996, Janssens et. al. 2004). This has inspired the notion of zones, a concept by which a number of sub areas of the building are defined. It is assumed that there exist no significant climate gradients in the animal's occupational zone. Figure 1 illustrates the concept where a building is partitioned into N zones.

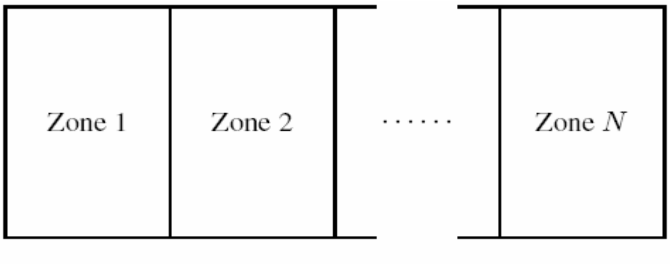


Figure 1. Series connection of $N$ zones.

The idea of multizone climate control is to have individual actuation of air inlets and outlets in each zone. This should be compared to conventional climate control systems where e.g. one motor is used to control all inlets simultaneously.

Centre for Embedded Software Systems (CISS) is in cooperation with Skov A/S investigating the possibility of doing zone based climate control in pig buildings, which has a number of prospective advantages, e.g. using warm air from a zone that need to be cooled down and redirect it (if air quality permits it) to zones with cooler air that need to be heated up. Differences in a building e.g. due to leakages or unconventional building structures could be compensated for with a zone based climate control system, which to some extend could provide a more accurate climate control. Since the building is divided into a number of zones, the building seen as one zone is over actuated. In case of actuator and/or sensor faults the controller can compensate e.g. by increasing the ventilation in neighbouring zones.

## Parameter Estimation

To implement zone based climate controller models of the climate are needed. Such models form the basis for the controller design and are as such inevitable. Now, much effort can be put into modelling of processes dependent of the application of the model. Computational fluid dynamics (CFD) models are often used for precise simulation purposes but are not really suitable for on-line control. Models based on physical knowledge can be more or less complicated dependent on the kind of controller that is being pursued; needless to say that e.g. PID control often suffices to use a first order model while MPC typically are based on more complicated models.

The approach taken is based on a more pragmatic attitude towards controller design using grey box modelling, which in short consists of identifying related parameters based on physical knowledge. Based on an estimation signal parameter estimation is used to find corresponding constants for the parameter relations.

Though we postpone the discussion of actually controlling the climate, we introduce the model that we believe is applicable for control purposes. Under the assumption that internal airflow between zones is the major cause for zone climate interaction, simple mass flow balance leads to the following model for the temperature $T_i$ in the $i^{th}$ zone:

$$V_i \frac{dT_i}{dt} = T^{amb} Q^{in}{}_i - T_i Q^{fan}{}_i + \left[Q_{i-1,i}\right]^{+} T_{i-1} - \left[Q_{i-1,i}\right]^{-} T_i - \left[Q_{i,i+1}\right]^{+} T_i + \left[Q_{i,i+1}\right]^{-} T_{i+1} + \frac{W^{T}{}_i}{\rho_{air} c_{air}}$$

where $V_i$ [m$^3$] is the zone volume, $T^{amb}$ [C] is the ambient temperature, $Q^{in}$ [m$^3$/s] is the airflow into the building, $Q^{fan}$ [m$^3$/s] is the airflow out from the building and $W^T{}_i$ [W] is the heat production from the animals. The internal flow between zones is defined by $Q_{i,i+1}$ that is positive from index i (left) to i+1 (right). The use of square brackets around the internal flows is defined as: $[x]^+ = \max(0,x)$ and $[x]^- = \min(0,x)$.

A problem arises with the introduction of zones, namely that for a given control signal we don't necessarily know the direction of the internal flows and thus we don't know which model should be used to implement a climate controller for. Since a building partitioned into N zones has N-1 zone boundaries and there are three possible flow directions (left, right, none) there are a total of $K=3^{N-1}$ possible models. But if an estimation signal is constructed that guarantees the direction of internal flow directions only one model exists. In the current work we have therefore suggested to use an estimation signal, which guarantees a specific internal flow direction combination, and to find the parameters for that model.

## Results

At our experimental facility (a building partitioned into three zones) we have found an estimation signal that guarantees the flow direction of internal flow to go from zone 1 to zone 2 and from zone 2 to zone 3. The signal is illustrated in figure 2, where $u_i^f$ denotes the actuation signal for outlets in the i$^{th}$ zone, and $\alpha_\iota$ denotes the actuation signal for the inlets in the i$^{th}$ zone.

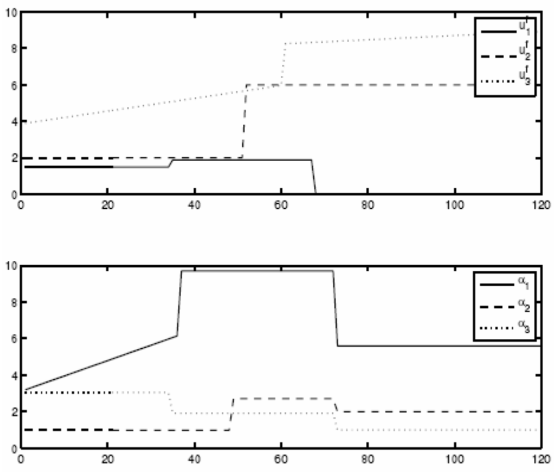

Figure 2. Illustration of actuator signals used as estimation signal for performing parameter estimation. The top graphs illustrates the signals for the outlet fans, the bottom graphs illustrates the signals for inlets.

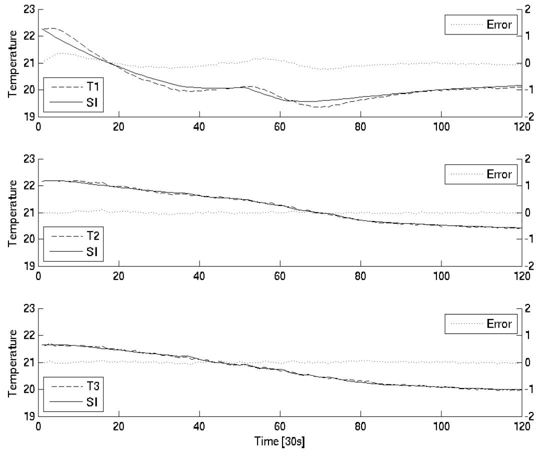


Figure 3. Illustration of recorded temperature in three different zones. Full line is the recorded temperature and dash-dotted is the simulated temperature using the found parameters. The dotted line is the error found by subtracting the simulated temperature from the recorded temperature.

Now, from the signals shown in figure 2 the corresponding temperatures in the three zones are recorded. The model presented in the above equation is reformulated as a linear combination of the different temperatures and actuator signals, and from the recorded temperatures the time derivative is found numerically. From the given estimation signal the corresponding parameters in the linear model can then be found using a mathematical identification procedure. Though we omit the discussion of the quality of the proposed method (in a system identification context) we simply use the found parameters to simulate the temperature using the actuator signals from figure 2. The result is illustrated in figure 3

## Future Climate Controller

Based on the found parameters the idea is to deduce all the possible models from that one model. For each of these models a controller can then be constructed automatically as well as an observer. The idea of the climate controller is illustrated in figure 4.

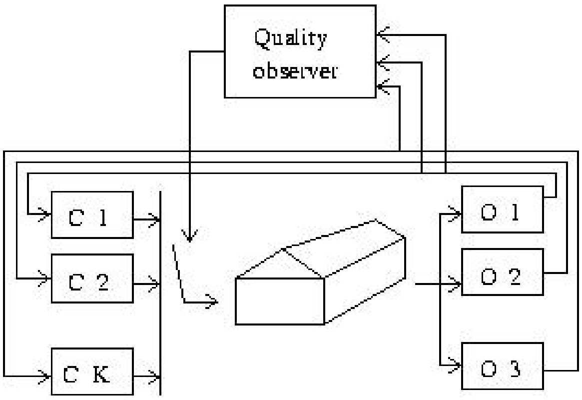


Figure 4 illustrates how we imagine the system to operate: From the parameter estimation procedure a total of K different models are found, and on basis of these models, K observers and controllers are constructed. Each observer furthermore outputs a quality estimate, which is feed into a quality observer. The quality observer then chooses the model description that fits bets, and consequently chooses which controller is used.

The purpose of the quality observer is to choose the model that currently has the best fit to the measured temperatures. As stated in the introduction we don't necessarily know the direction of the internal flows and hence we don't know which model should be used to control the climate. With the proposed method we hope that we'll be able to construct the K observers and controllers automatically and test it at our experimental facility. The rest of the work is being conducted in the autumn 2006.

### References:

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