Accurate, adaptive, and predictive self-learning control of heating

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Structure

- Problem statement
- PI control theory
- Time constant calculation methods
- Efficiency of setback control
- Open questions
- The End
Problem at hand

- Shift from immense heat emission to temperature set-point following approach
  - severely over-dimensioned systems difficult to control with only P-controllers

- Idea to have autonomous room-based PI controllers with automated calculation of parameters

- Difference between measured and simulated controller outputs as
  - real systems like black boxes
  - simulated systems often close to ideal
  - default parameters often used
Some theory

\[ e = T_{\text{set}} - T_{\text{measured}} \]

\[ u_n = u_{n-1} + \frac{K_p \cdot (e_n - e_{n-1})}{t_i} + K_p \cdot \frac{t}{t_i} \cdot e_n \]

**Proportional**

**Integral**

\[ K_p = \frac{1}{1.1K} \left( \frac{\tau}{t_v} \right) \]

\[ t_i = 3.5t_v \]

\[ \tau - \text{time constant} \]

\[ t_v - \text{time lag} \]

\[ K = \frac{\Delta T}{\Delta u} \]
Conducted research >> Time constant

- **Motivation:**
  - Time constant used for PI parameter calculation
  - Different methods for time constant estimation exist

- **Methods:**
  - Three different time constant calculation methods applied
  - Constant PI parameters calculated

\[ \tau = \frac{C}{H} \]

- \( C \) – thermal capacity (J/K)
  - tabular values (light/heavy)
  - calculated values (20/100mm)
- \( H \) – heat loss coefficient (W/K)
  - Ventilation and transmission

1) \[ \tau = \frac{C}{H} \]

2) 

<table>
<thead>
<tr>
<th>Time (h)</th>
<th>Temperature increase (K)</th>
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</thead>
<tbody>
<tr>
<td>0</td>
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<tr>
<td>20</td>
<td>1.5</td>
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<td>40</td>
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<td>60</td>
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<td>80</td>
<td>3.5</td>
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<td>100</td>
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3) 

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Do you know any other methods? Tell me 😊

Have you used any of these methods? Did they work for your case?

27.09.2018
T. M. Kull – Modelling of heating control systems
Conducted research >> Time constant

**Problems:**
- Time lag often reduces to zero, fixed minimum value used
- How to correctly estimate the steepest slope (running mean)

**Results:**
- Very different time constants
- Problems controlling underfloor heating with a PI controller
- Problems handling internal gains with PI controller

\[ K_p = \frac{1}{1.1K} \left( \frac{\tau}{t_v} \right) \]

Have you tried estimating the slope on measured data?
Conducted research

1. Time constant influence on heating control *(NSB 2017)*

2. Setback efficiency *(CCHVAC 2018)*

3. MPC for storing energy in the room’s thermal mass *(journal paper submitted)*
Conducted research >> Setback efficiency

- **Motivation:**
  - Used in central Europe but not in Nordics
  - Check the effect for low energy buildings

- **Methods:**
  - Heat-up time estimation for every timestep
  - Setpoint changed if heat-up different than expected

- **Results:**
  - The effect of intermittent heating is very low in energy-efficient buildings

<table>
<thead>
<tr>
<th></th>
<th>Setback efficiency (kWh/m²a)</th>
<th>Setback efficiency (%)</th>
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<td>5%</td>
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</tr>
<tr>
<td>S_H_Rad</td>
<td>5%</td>
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<tr>
<td>S_L_UFH</td>
<td>6%</td>
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<td>S_L_O_Rad</td>
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$t = -\tau \cdot \ln \left( \frac{\Phi/H - \theta_{set} + \theta_{out}}{\Phi/H - \theta_{in} + \theta_{out}} \right)$

$\tau = \frac{C_{20mm}}{H}$

First letter:

- O – old
- S – standard
- M – modern

Use setback control algorithm? How did you estimate the time for setpoint change?
Preview of tasks lying ahead

- Focus on the methods for modelling heating system together with their controllers in low energy buildings
  - Determine needed level of detail

- Calibration of two buildings with the focus on their heating system and control:
  - Test House at TalTech Campus
  - Student Family Dormitory at TalTech Campus

- Testing ideas how to build a control that works efficiently also with
  - over-dimensioned systems
  - floor heating
  - extensive internal heat gains

Do you know someone who knows all this theory and could help me with methodology?

Do you know any working control algorithm for floor heating?
Open questions

- Have you used any of the time constant calculation methods I used? Did they work for your case? Did you have any differences in the methods?

- Do you know any other methods?

- Have you tried estimating the slope on measured data? How did you average out the small fluctuations?

- Have you written setback control algorithm? How did you estimate the point of time when to change the setpoint?

- Do you know any working control algorithm for floor heating?

- Suggestions for cooperation?
THANK YOU FOR YOUR ATTENTION!

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