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

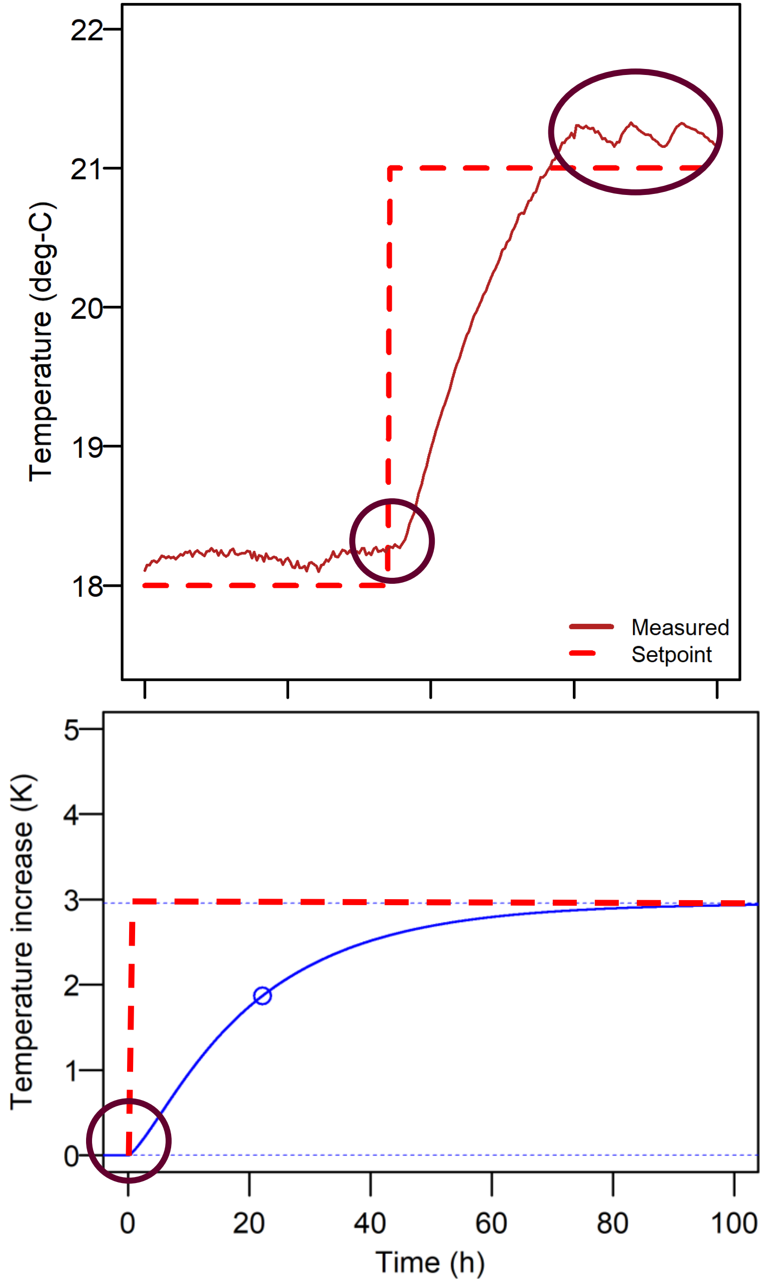
- Shift from immense heat emission to temperature set-point following approach

  → 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

PI:

$$u_n = u_{n-1} + \overbrace{K_p \cdot (e_n - e_{n-1})}^{\text{Proportional}} + \overbrace{K_p \cdot \frac{t}{t_i} \cdot e_n}^{\text{Integral}}$$

$$e = T_{set} - T_{measured}$$

t – *sampling interval*

P $$K_p = \frac{1}{1.1K}\left(\frac{\tau}{t_v}\right)$$

I $$t_i = 3.5 t_v$$

τ – *time constant*

t_v – *time lag*

$$K = \frac{\Delta T}{\Delta u}$$

Conducted research >> Time constant

Do you know any other methods? Tell me ☺

- **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

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

1) $$\tau = \frac{C}{H}$$

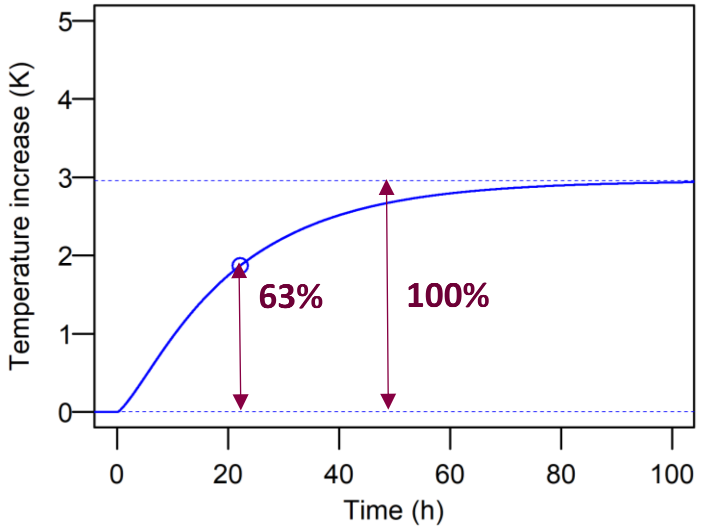
C – thermal capacity (J/K)

- tabular values (light/heavy)
- calculated values (20/100mm)

H – heat loss coefficient (W/K)

- Ventilation and transmission

2)



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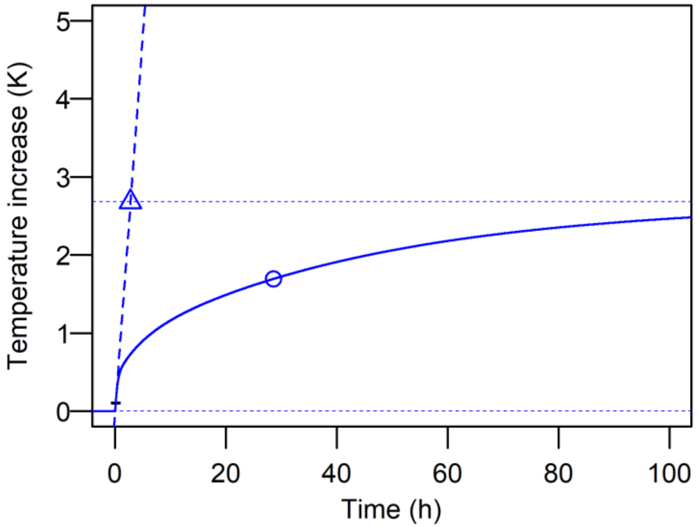
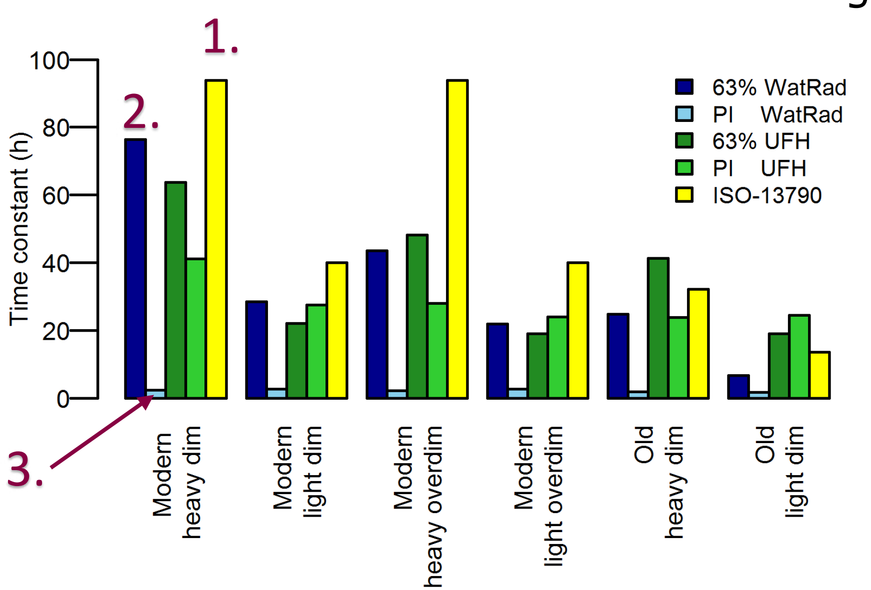


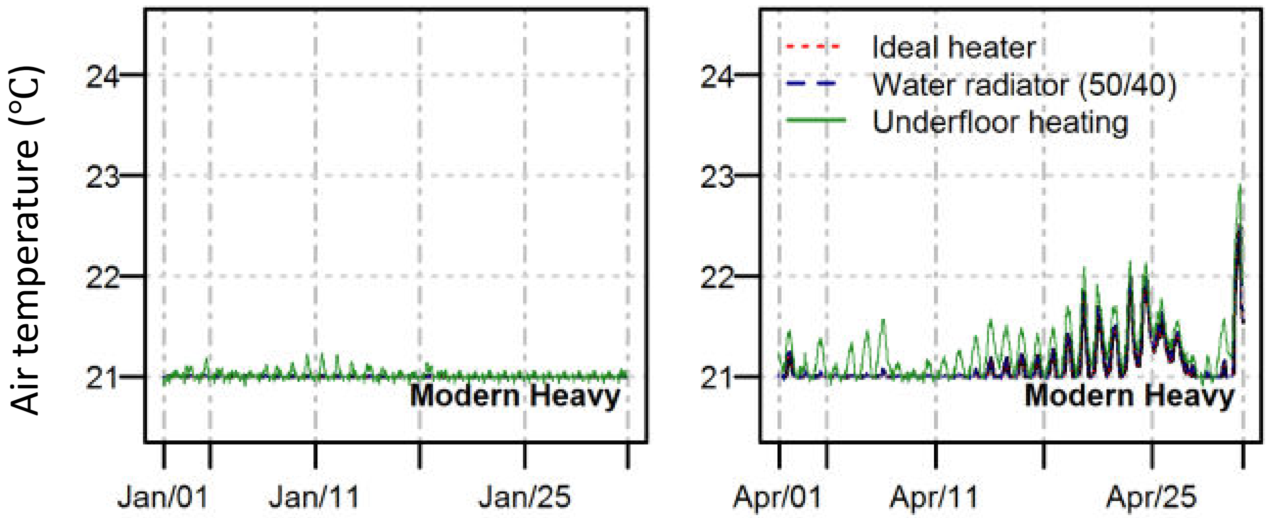
Conducted research >> Time constant

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

- **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

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

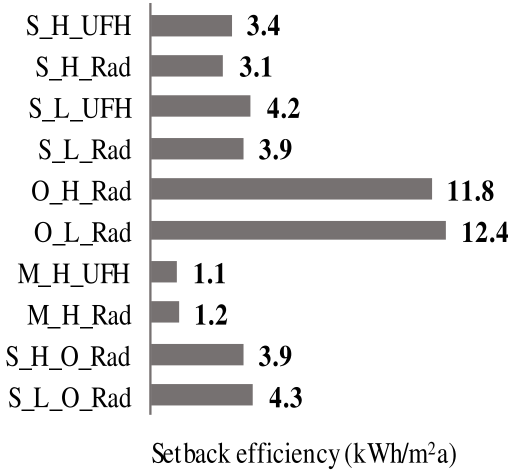
- **Motivation:**
  - Used in central Europe but not in Nordics
  - Check the effect for low energy buildings
- **Methods:**
  - Heat-up time estimation for every timestep
  - Setpoint changed if heat-up different than expected
- **Results:**
  - The effect of intermittent heating is very low in energy-efficient buildings

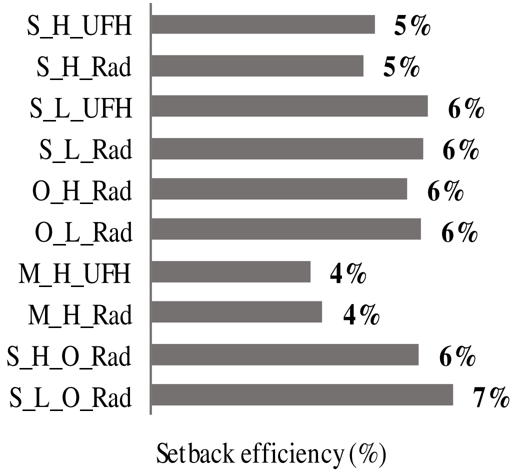
Heating power / Heat loss coefficient / Temperatures

$$t = -\tau \cdot \ln\left(\frac{\Phi/H - \theta_{set} + \theta_{out}}{\Phi/H - \theta_{in} + \theta_{out}}\right)$$

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

Have you written setback control algorithm? How did you estimate the time for setpoint change?





First letter:
O – old
S – standard
M – modern

TTÜ100

Preview of tasks lying ahead

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

- 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 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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