Optimal control of HVAC up to component level using white-box MPC -

Brains for building energy systems

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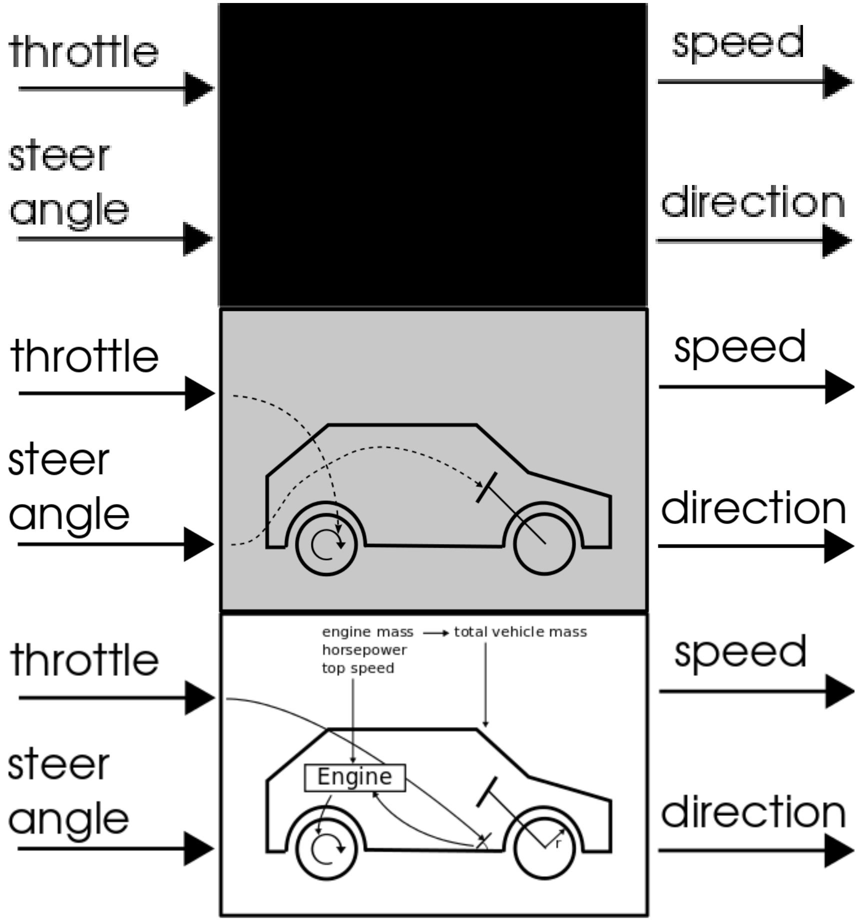
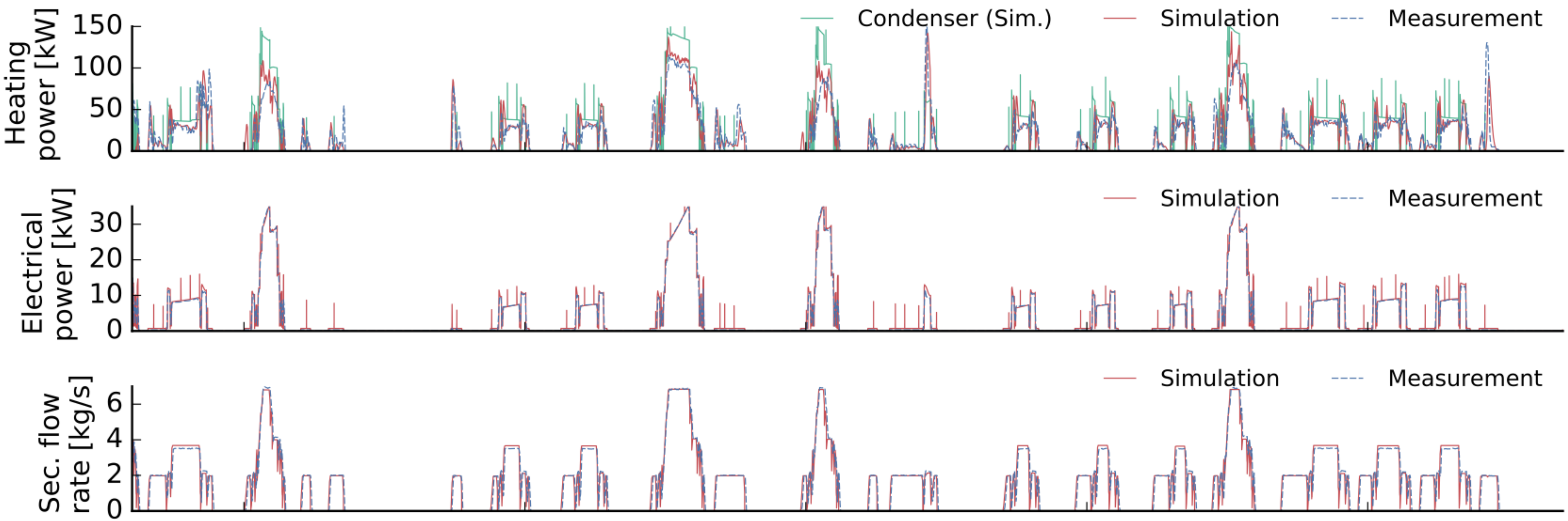
Model predictive control types

- Black-box:
  - Data-driven, typical AI
- Gray-box:
  - Fitting parameters to physics-based models
- White-box
  - Purely physics-based models
- *Detailed* white-box
  - Up to component level, replaces RBC



Motivation for detailed white-box

- Why *learn* what we already know?
  - Example: heat pump power and COP based on white-box model



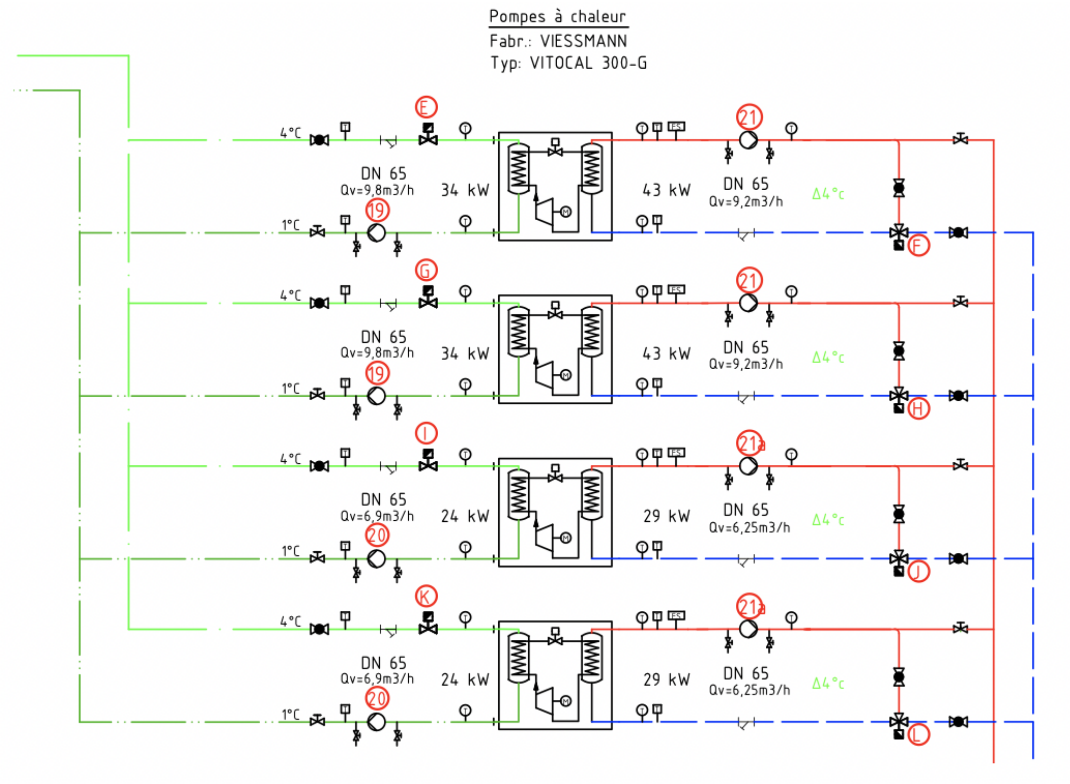
Motivation for detailed white-box

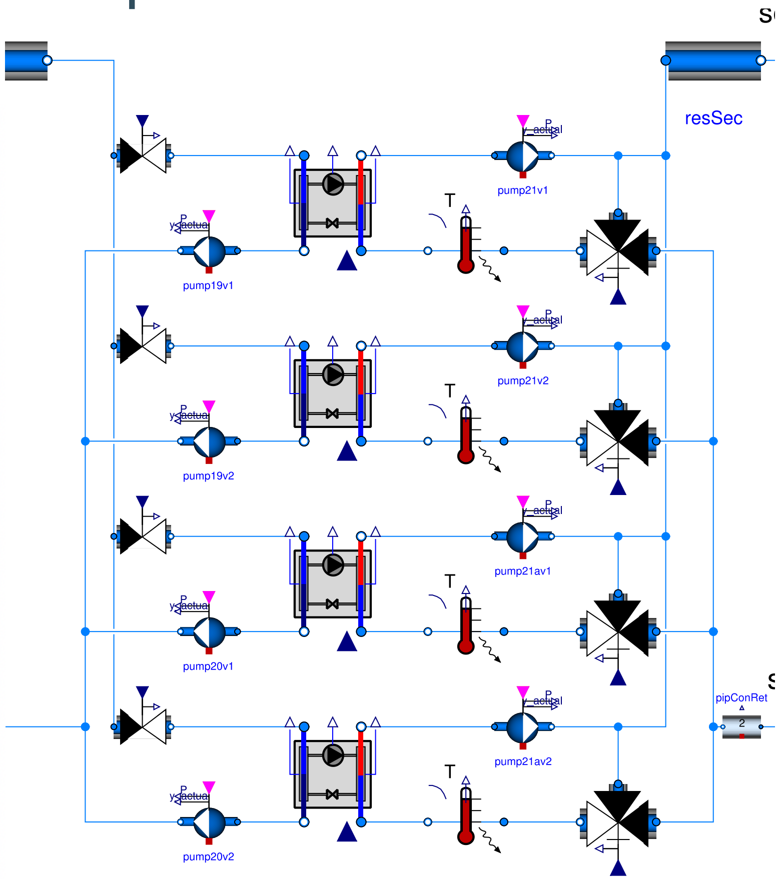
- Why *learn* what we already know? (And hope you get it right)
- More detail; more optimization potential
  e.g. fan power based on pressure drops
- Potential to replace RBC: less investment, less commissioning
- Flexible: Easy to switch objective, make model updates, model re-use, …

- However:
  - “Too slow” (but not really)
  - Requires custom model development -> automation, BIM

Approach

- One-to-one mapping of components into component models (Modelica/IDEAS)





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Toolchain

[1] F. Jorissen, G. Reynders, R. Baetens, D. Picard, D. Saelens & L. Helsen (2018) Implementation and verification of the IDEAS building energy simulation library, Journal of Building Performance Simulation,11:6, 669-688, DOI: 10.1080/19401493.2018.1428361
[2] F. Jorissen, W. Boydens & L. Helsen (2019) TACO, an automated toolchain for model predictive control of building systems: implementation and verification, Journal of Building Performance Simulation, 12:2, 180-192, DOI: 10.1080/19401493.2018.1498537

Demonstration case; hybridGEOTABS

Fluvius & Boydens engineering offices Dilbeek

- 3000 m^2
- GEOTABS + VAV

hybrid GEOTABS

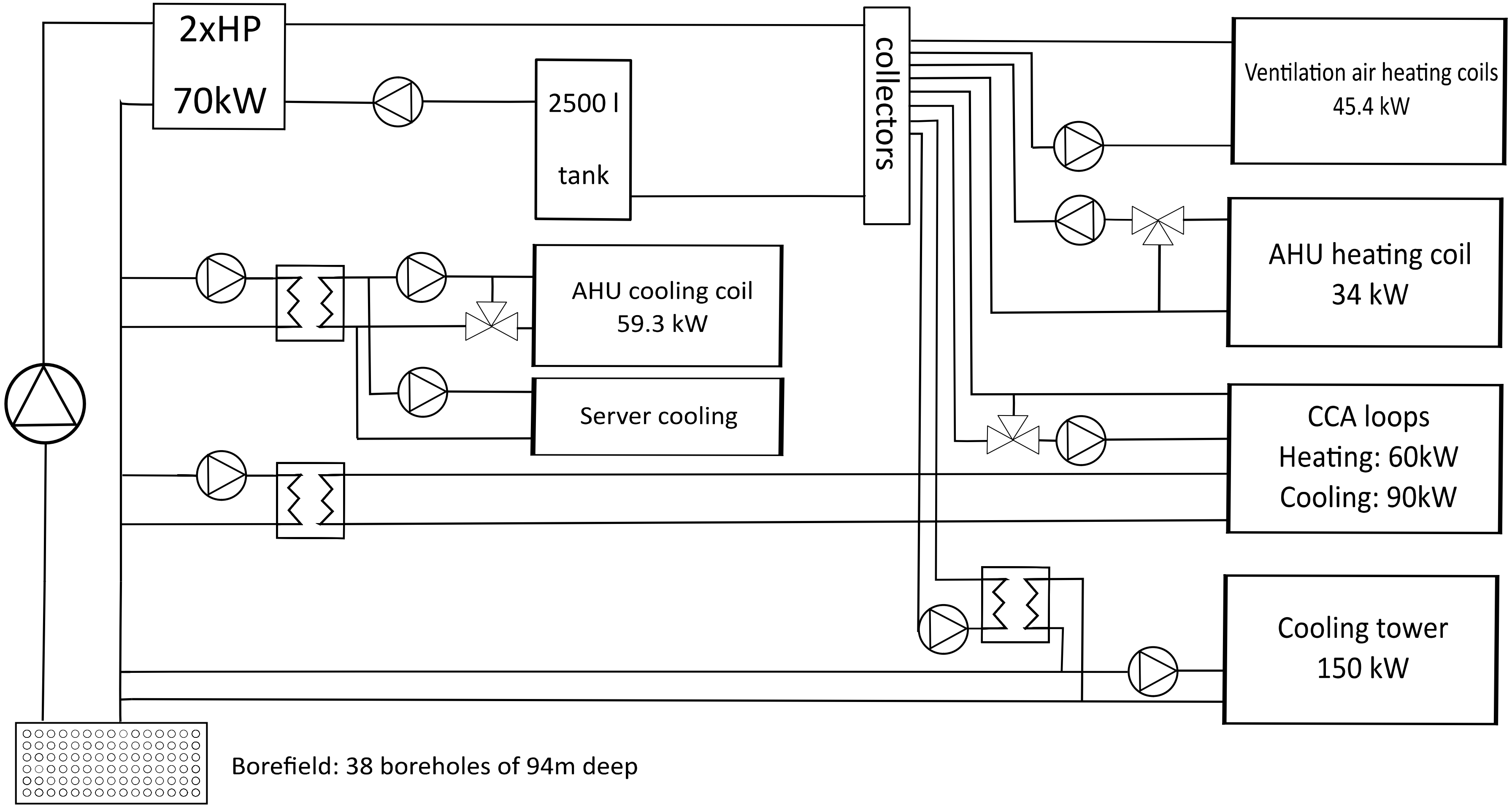
PRIVA

fluvius.

boydens engineering
technology and energy

Control variables:

- HP temperature
- 15 x VAV
- 2 fan diff. pressures
- 8 x 2-way valve
- 5 x 3-way valve
- pump flow rates
- pump heads



hybridGEOTABS demonstration results

- MPC statistics:
  - 1288 states
  - 13 625 time-varying variables
  - 49 control variables
  - 15 minute updates
  - 3 day horizon
  - ~ 1 minute optimization time

Statistics

Original Model
Number of components: 18178
Variables: 371880
Constants: 1758 (1762 scalars)
Parameters: 150400 (168406 scalars)
Unknowns: 219722 (221409 scalars)
Differentiated variables: 1556 scalars
Equations: 65224
Nontrivial: 58188

Translated Model
Constants: 136703 scalars
Free parameters: 25666 scalars
Parameter depending: 44246 scalars
Inputs: 56 scalars
Outputs: 211 scalars
Continuous time states: 1288 scalars
Time-varying variables: 13625 scalars
Alias variables: 171337 scalars

Conclusion

- Detailed, component based optimal control
- First demo running, two more in the pipeline, looking for more
- Potential for model re-use for design, retrofit, fault detection, etc

More information & thanks to

- http://taco.sysi.be
- http://ideas.sysi.be
- http://hybridgeotabs.eu
- F. Jorissen. Toolchain for Optimal Control and Design of Energy Systems in Buildings. Phd thesis, Arenberg Doctoral School, KU Leuven, April 2018.

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