Methodology for Obtaining Linear State Space Building Envelope Models

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Heating, Ventilation and Air Conditioning (HVAC) equipment for building systems consumes around 18 % of the total end energy in Europe[1]. One way of reducing energy use in buildings is to use optimal control techniques such as Model Predictive Control (MPC). MPC is facilitated by linear, low-order models of the building structure and of its HVAC systems. However, obtaining these models in a practical form is often difficult, which greatly hampers the commercial implementation of optimal controllers. This work describes a methodology for obtaining a linear state space model of building energy simulation (BES) models, consisting of walls, windows, floors and the zone air. The methodology uses the Modelica library IDEAS to develop a BES model including its non-linearities and automates its linearisation in Dymola. All non-linear equations were identified and either linearised or moved outside of the model by replacing them by input signals, as shown in Figure 1. Dymola function `Linearize2` is used to generate the state space model (SSM) of the now linear model, facilitating further mathematical manipulations, or simulation in different environments.

The methodology is illustrated for an office building. The obtained 50 state SSM shows a maximum zone temperature error of 1 K and a mean deviation of 0.21 K compared to the non-linear BES model. We further show that applying model order reduction to the original SSM still generates excellent predictions for model orders up to 15 states. The low order but high accuracy of the reduced model makes it very suitable for applications such as MPC.

[1]L. Perez-Lombard, J. Ortiz, and C. Pout. A review on buildings energy consumption information. Energy and Buildings, 40 (3):394–398, 2008.

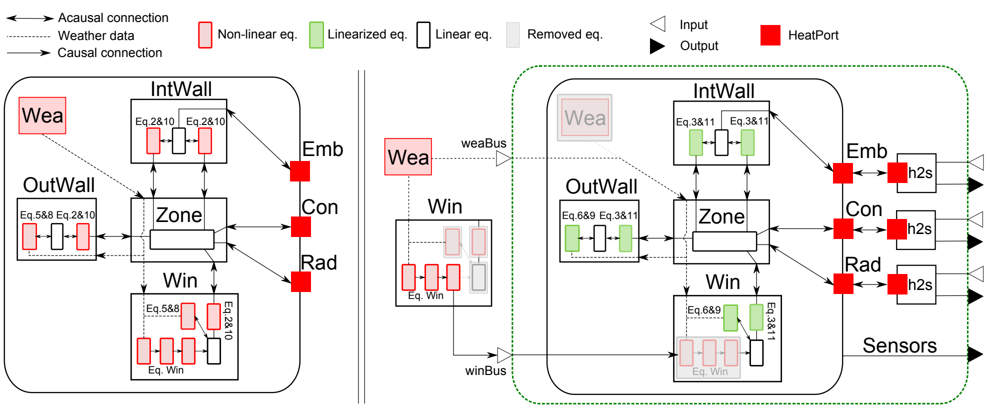

Figure 1. Left: original model with non-linear equations. Right: Adjusted model structure with moved and/or linearized non-linear equations. Component models are outer wall 'OutWall', interior wall 'IntWall', Window 'Win', weather model inputs 'Wea' and HeatPorts 'Emb', 'Con' and 'Rad'.