Setting up a framework for model predictive control with moving horizon state estimation using JModelica

Mats Vande Cavey, Roel De Coninck, Lieve Helsen,
KU Leuven, Department of Mechanical Engineering, 3001 Leuven
mats.vandecavey@mech.kuleuven.be, roel.deconinck@mech.kuleuven.be,
lieve.helsen@mech.kuleuven.be

A framework is proposed that allows using Modelica models in a model predictive control framework with state estimation. The aim of the framework is to optimally control the heating of a building. The contribution lays in the implementation of the moving horizon estimation (MHE) using JModelica [FIXME ref] and Modelica models.

This framework is applied to heating control of a residential, single zone building. The controller model is a low order resistance-capacitance (RC) building model. The emulator is a ‘detailed’ Modelica model of the building and heating system. MHE is a state estimator which determines the (controller) model error for each state over a past time window. This is done by optimizing the trajectories of every state’s model error over that past time window, to fit the measurements of one (or more) state(s). To this end, instead of the typical deterministic Modelica equations, the controller model needs to be formulated using stochastic equations for the states and ***w*** is formulated as an input to the Modelica model:

$$C * \frac{d(T)}{dt} = Q_{flow} + \boldsymbol{C} * \boldsymbol{w} \qquad (1)$$

$$\frac{\boldsymbol{d(\Delta T)}}{\boldsymbol{dt}} = \boldsymbol{w} \qquad (2)$$

The optimization problem is formulated as a least squares problem (3) with a different weighting for the terms:

$$\min_{x0,\{w_k\}_{k=T-N}^{T-1}} \sum_{k=T-N}^{T-1} \|v_k\|^2_{R^{-1}} + \|\Delta T_k\|^2_{Q^{-1}} \qquad (3)$$

The weighting factors $R^{-1}$and Q^{-1} denote the inverse of the covariance matrices of the measurement noise v_k and the model error (process noise) ΔT_k. If the covariance matrices are unknown, $R^{-1}$and Q^{-1} can be tuned in order to produce good results.

The input variable w is the result of the state estimation. Multiplied by the capacity C, the term represents an extra heatflux. It is linked to the model temperature through the state equation (1) and the end temperature difference ΔT of the MHE decides the new start temperature of the OCP. In Figure 1 the improvement of applying state estimation is shown, as the real zone temperature is kept closer to the optimal one.

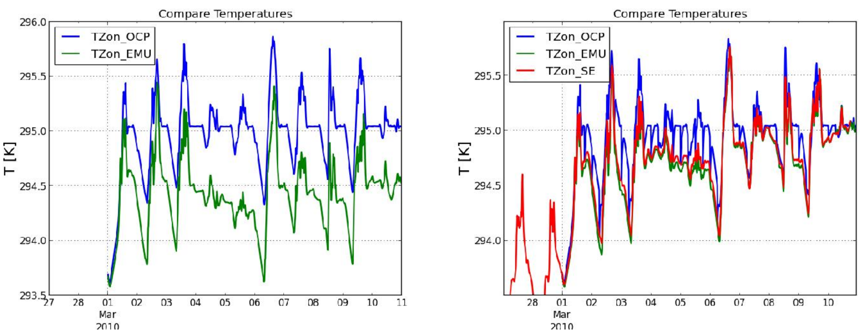

Figure 1: Comparing zone temperatures without (left) and with (right) state estimation