# Adaptive and Predictive Air Conditioning Control

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*The control of the hygro-thermal conditions within private and public buildings to maintain optimal user comfort is contributing to one third to the total energy consumption in Switzerland according the Analysis Report of the Swiss Federal Office of Energy. It also directly impacts the global carbon dioxide ($CO^2$) emissions and the user's energy bill. Given the ever increasing energy consumption and challenging objectives in terms of $CO^2$ reduction, there is an urge to minimize the energy linked to the hygro-thermal regulation without compromising user comfort. The objective of the project NeuroCool, is to drive the air handling unit in an efficient way that minimizes the exploitation costs and satisfies user comfort.*

Two parallel trends exist in order to reduce the energy consumed for HVAC (heating, ventilation and air-conditioning). The first consists in retrofitting the building by, typically, replacing windows, insulation and other elements of the building structure. Even the impact of these retrofitting measures on the building structure is considerably reducing the energy consumption, the associated costs are high and the payback time often exceeds 10 years. The second approach consists in replacing the standard HVAC controller with a more efficient controller. The latter option can take advantage of weather forecasts and building characteristics in order to find an optimal heating or cooling strategy that minimizes the exploitation costs while maintaining user comfort. This option only requires the installation of a minimal set of additional sensors and the adaptation to an increased computational power, leading to shorter payback time than with the retrofitting option.

NeuroCool is a 24 months CTI project with Neurobat AG as industrial partner and the HEIG-VD and CSEM as research partners. NeuroCool is a novel Model-Predictive Control (MPC) based algorithm for HVAC[1]. The algorithm relies on a self-adaptive data-driven model of the building hygro-thermal behavior which is used to predict the temperature and humidity in the building as a function of excitations that include the pulsed air (temperature, humidity and flow) and the weather (temperature and solar radiation). The model is used by the optimization procedure to guarantee that the indoor conditions are kept within the European norms in terms of zone temperature and humidity. The optimization procedure also takes into account the costs associated with heating/cooling and (de-)humidification in order to find the most cost efficient solution.

In the frame of this project, three test sites[2] have been equipped with the developed solution: i) a climatic chamber facility at the HEIG-VD, ii) two tests rooms at CSEM facilities, and iii) one administrative building in Winterthur. The two first test sites have been modelled in Matlab-Simulink and extensive simulations under various climatic conditions and comfort settings have been carried out. For the CSEM facilities, simulation results are shown in Figure 1. The simulation conditions have been set to 100 days starting in June and with different comfort settings. The comfort is controlled by adjusting a weighting factor λ in the optimization loop. This factor controls the weighting between energy and comfort. The plot highlights the energy consumption (kWh) and comfort (PMV, as defined in [3]) for different values of λ. A perfect comfort corresponds to a PMV of 0. Note that if the comfort boundaries, as defined by the European norms, are respected, the PMV is comprised within -0.5 and 0.5. Figure 1 shows that the comfort can be controlled by adjusting (i.e. reducing) λ. As expected, lower comfort levels result in decreased energy expenditure.

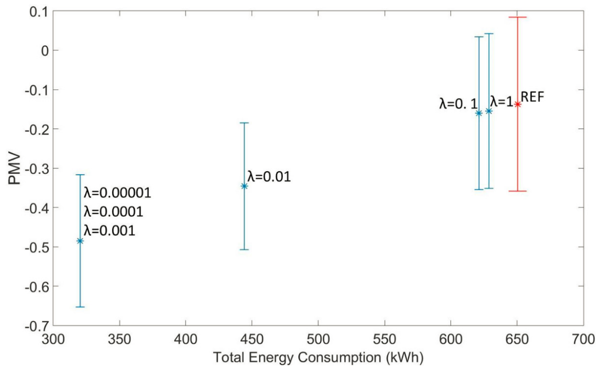


*Figure 1: Simulation results for CSEM test facilities with comfort (PMV) versus energy consumption (kWh). NeuroCool (in blue), and standard controller (in red). For NeuroCool, different comfort settings are provided.*

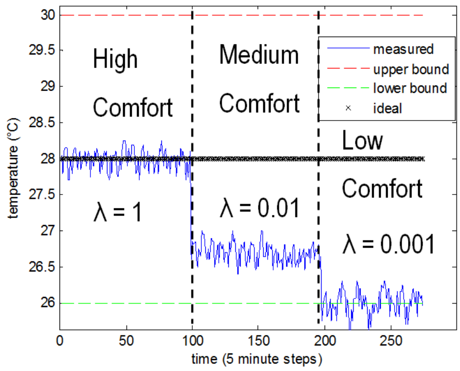


*Figure 2: Test site facility results from HEIG-VD: the measured room temperature as a function of time is displayed for different comfort settings.*

Preliminary test results from the HEIG-VD facilities are shown in Figure 2. As validated during the simulation study, various comfort levels can be achieved by controlling the weighting factor λ. Furthermore, stable operation is obtained even under unfavorable operating conditions. Deployment on the two remaining test sites are being undertaken in 2015 and detailed results will be provided with the end of the project in 2016.

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[1] Y. Stauffer, *et al.*, Neurocool: an adaptive, model-predictive control algorithm for ventilation and air conditioning systems, Clima 2016, abstract accepted

[2] Y. Stauffer, *et al.*, Neurocool: field tests of an HVAC control algorithm, Clima 2016, abstract accepted

[3] ANSI/ASHRAE Standard 55-2010, Thermal environmental conditions for human occupancy