TRIBUTE—Automatic Building Simulation Model Calibration and Diagnostics

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In the frame of the European FP7 project TRIBUTE, CSEM developed novel methods for the automatic calibration of Building Energy Performance Simulation models with the aim of reducing the gap between the building's predicted and measured energy consumption. Such a calibrated model allows real-time monitoring of the building's energetic evolution and the diagnosis of misbehaviors.

Buildings account for more than 40% of energy consumption and 36% of CO_2 emissions in the EU. The EU Energy Efficiency Directive[1] establishes a set of binding measures to be implemented by EU members by the end of 2016 in order to reach a 20% energy-efficiency target by 2020. In order to reach this target, Building Energy Performance Simulation (BEPS) tools are widely used for modern mid-size to especially large buildings and thus throughout the full life cycle of such buildings. These models, if used throughout the building commissioning phase, might become a powerful means of helping building operators and facility managers to assess building energy performance, detect anomalies, and suggest management improvements. Nevertheless, today's BEPS models are largely insufficient, showing significant discrepancies between measured and computed building energy performances, limiting their applicability.

In the frame of the TRIBUTE project, based on a set of deployed sensors, methods that allow for automatic calibration of the underlying simulation model were developed. By continuously learning from operation, the results from TRIBUTE show a 15% reduction of the energy gap on test sites. The development of TRIBUTE relies on the IDA Indoor Climate and Energy (IDA-ICE) tool developed by EQUA Simulation AB, one of the TRIBUTE's partners. IDA-ICE is a whole-building simulation tool based on dynamic multi-zone calculations and provides results on thermal indoor climate and energy consumption. The proposed TRIBUTE method relies on three steps. First, the simulation model is established and a first simulation model calibration is performed. Second, a sensitivity study is performed, allowing determination of the simulation model parameter that has the largest influence on the building energy performance. Third, these parameters will be continuously learnt, while their evolution will indicate building ageing or faults. These developments are currently validated on a public building in La Rochelle France, namely the Vaucanson building, which is depicted in Figure 1. Figure 2 shows the results of the second step with the most critical parameters that need to be calibrated.

Figure 1: La Rochelle building, IDA-ICE 3D view.

[1] Directive 2012/27/EU of the European parliament and of the council of 25 October 2012 on Energy Efficiency.

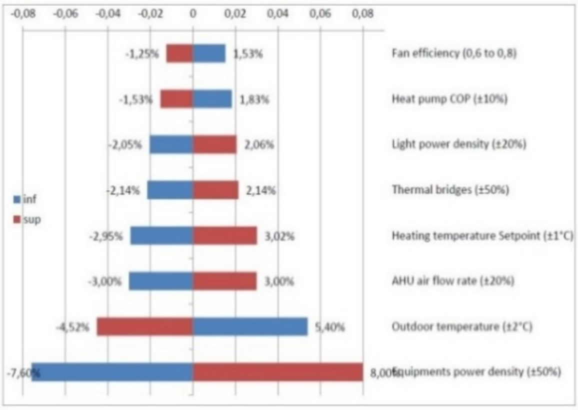

Figure 2: Impact of the most influential parameters on the total energy consumption of La Rochelle building model.

CSEM developed a calibration method based on a Support Vector Regression (SVR) method. A meta-model for the cost function is created by means of SVR. An example is shown in Figure 3 below, where the sensitivity of the cost function is illustrated in a 3D view for two parameters (on the left) and in 2D views for four parameters (on the right). As such, the SVR method offers a visual high-order sensitivity analysis tool. Based on such meta-models, the calibration procedure subsequently applies optimization, which is either gradient-based (such as the Levenberg-Marquardt algorithm) or gradient-free (such as the Nelder-Mead method). So far, the optimization aims at minimizing temperature error and total required power, both restricted to a certain zone. Two metrics were considered: the mean bias error and the Coefficient of Variation of the Root Mean Square Error (CVRMSE). For the La Rochelle building, a 15% error reduction has been achieved.

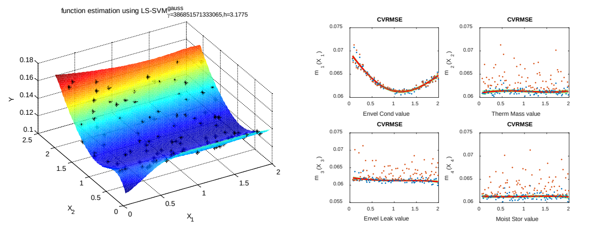

Figure 3: SVR meta-model cost function with two parameters (left) and four parameters (right).

The developed calibrated model lays the base for detecting building anomalies. The work has been carried out in the collaborative project TRIBUTE (http://www.tribute-fp7.eu) and is partly funded by the 7th Framework Program of the European Union (grant agreement no. 608790).