International
Building
Performance
Simulation
Association

Year 3 Status Report IBPSA Project 1: BIM/GIS and Modelica framework for building and community energy system design and operation

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September 11, 2020

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1 Introduction

IBPSA Project 1 had a productive year, with the an expert meeting held in Rome in August 2019, and a virtual expert meeting held in May 2020. Both were attended by around 50 people.

Each of the three tasks had several coordination meetings. Funding for the continued collaboration has been secured by many of the key participants.

2 Management of the Project

As of September 9, 2020, there are 29 organizational participants and 49 individual participants. Engie Lab is a sponsoring participant. A full list of the participants can be found at https://ibpsa.github.io/project1/participation.html and a list of meetings with their minutes is available at https://github.com/ibpsa/project1/wiki/Meetings.

3 Progress of the activities

Task 1: Modelica

WP 1.1: Library for design and operation

The former IEA Annex 60 library has been renamed to *IBPSA Library* and is posted under a BSD license at https://github.com/ibpsa/modelica-ibpsa

The development of the Modelica IBPSA Library, hosted at https://github.com/ibpsa/modelica-ibpsa, is actively ongoing, with monthly coordination meetings. A main addition this year are models for

- borefields,
- pressure independent air dampers,
- three-way control valves with opening characteristics provided through user-defined table, and
- BESTEST simulation for weather data.

Improvements have been done to models for

- weather data (to allow user-supplied data that do not cover 1 year, and to overwrite weather data with constant values for steady-state simulation), and
- thermal zones using a reduced order model that allows now also tracking of trace substances such as CO2.

Also, many icons have been refactored so that the simulation dynamically shows current temperatures, flow rates, sensor and actuator signals.

The library is used at the core of the Modelica libraries

- AixLib, from RWTH Aachen University, Germany: https://github.com/RWTH-EBC/AixLib
- Buildings, from LBNL, Berkeley, CA, USA: http://simulationresearch.lbl.gov/modelica
- BuildingSystems, from UdK Berlin, Germany: http://www.modelica-buildingsystems.de
- IDEAS from KU Leuven, Belgium: https://github.com/open-ideas/IDEAS

WP 1.2: Model Predictive Control

Three main tasks were defined, i.e. Using Modelica

1. To develop a framework to test and assess MPC performance
2. To compare and benchmark different MPC formulations
3. To develop an open-source Library for MPC

The developments are actively ongoing, with monthly coordination meetings. The main activity was focused on the continued development (maintenance and feature enhancements) and prototype testing of the Building Optimization Performance Test framework (BOPTEST). BOPTEST allows testing of advanced control sequences on a range of models that emulate the response of the building and HVAC system. Emulators are being developed (some of them have been finalized and undergone a peer review based on the test case peer review document) for single-zone and multi-zone residential and commercial buildings for both air-based and hydronic HVAC systems, quantitative performance indicators have been integrated as a calculation module in the BOPTEST framework, the prototype BOPTEST is ready and now being tested by different institutes using their own-developed MPC algorithms, a web interface for BOPTEST to store and present test results and show other information about test cases is being developed, and first steps are taken to generate data sets for uncertain forecasts to be used by the BOPTEST users. In a next step, starting from the IBPSA library we will develop a library of models (IbpsaMpc) that can be used to efficiently solve optimal control problems for building and district energy systems (and that can be combined with parameter and state estimation algorithms). Moreover, we will reflect on how we can broaden the user space to e.g. the Machine Learning Community.

Publications:

Contribution to IBPSA Newsletter, 2020

D. Blum, F. Jorissen, S. Huang, Y. Chen, J. Arroyo, K. Benne, Y. Li, V. Gavan, L. Rivalin, L. Helsen, D. Vrabie, M. Wetter, and M. Sofos. (2019). Prototyping the BOPTEST framework for simulation-based testing of advanced control strategies in buildings. In Proc. of the 16th International Conference of IBPSA, Sep 2 – 4. Rome, Italy. Available from http://www.ibpsa.org/building-simulation-2019

Ján Drgona, Lieve Helsen, Draguna Vrabie. (2019). Stripping off the implementation complexity of physics-based model predictive control for buildings via deep learning. Conference on Neural Information Processing Systems, December, 2019.

D.H. Blum, K. Arendt, L. Rivalin, M.A. Piette, M. Wetter, C.T. Veje. (2019). Practical Factors of Envelope Model Setup and Their Effects on the Performance of Model Predictive Control for Building Heating, Ventilating, and Air Conditioning Systems. Applied Energy , Vol. 236, p. 410 - 425.

Javier Arroyo, Fred Spiessens, Lieve Helsen (2020). Identification of multi-zone grey-box building models for use in model predictive control. Journal of Building Performance Simulation, Vol. 13, p. 472-486.

Ján Drgoňa, Javier Arroyo, Iago Cupeiro Figueroa, David Blum, Krzysztof Arendt, Donghun Kim, Enric Perarnau Ollé, Juraj Oravec, Michael Wetter, Draguna L. Vrabie, Lieve Helsen (2020). All you need to know about model predictive control for buildings.: Annual Reviews in Control – accepted.

Abstracts submitted to BS2021 Conference:

Javier Arroyo, Carlo Manna, Fred Spiessens and Lieve Helsen (2020). Reinforced Model Predictive Control for Building Energy Management

Filip Jorissen, Damien Picard and Lieve Helsen (2020). Automated workflows for optimal design and control of buildings using Modelica

Task 2: Building and City Quarter Information Models

WP 2.1: City District Information Modeling

After having identified that our target scale is the urban district (for us meaning a scale of 100s to 1000s of buildings) and that our target scope is on the energy simulation of domestic and non-domestic buildings, the following priorities were agreed:

1. Data mapping: defining the questions to which modellers seek answers and the candidate tools available to answer them, the data needs of these tools, the country-specific data available and candidate strategies for plugging the gaps. A draft data availability mapping template has been prepared.
2. Archetypical definitions: country-specific categorisations of age bands and archetypal geometric forms for both domestic and non-domestic buildings, and strategies for the automated classification of age and form. This is to facilitate the association of semantic attributes to the built forms.
3. Parsimonious semantic enrichment: workflows for the acquisition and sanitation of semantic attribute data, the assignment of attributes to 3D models using this data, and for the plugging of gaps where attributional data is unavailable or of poor quality.
4. Identification and quantification of uncertainties for district level energy simulations.
5. Virtual Reality applications for 3D city models.

Publications:

Avichal Malhotra, Eric Fichter, Gerald Schweiger, Jérôme Frisch, Christoph Alban van Treeck. IBPSA Project 1: Update on city quarter and building information modelling. In Ibpsa news, Volume: 30, Issue: 1,

Page(s): 31-35.

Avichal Malhotra, Julian Bischof, James Allan, James O'Donnell, Thomas Schweiger, Joachim Benner, Gerald Schweiger (2020). A Review on country specific data availability and acquision techniques for city quarter information modelling for building energy analysis. In proceedings of the 8th German-Austrian IBPSA Conference BauSIM 2020: September 23th - September 25th / Publisher TU Graz.

WP 2.2: Building Information Modeling

The current work in Task 2.2 was focusing on transforming building information models towards building performance simulation. Furthermore, a common toolchain is developed for simulations in the Modelica based TEASER library and in EnergyPlus.

Starting with the import of the IFC file to Python using IfcOpenShell, generic python instances of the IFC entities are created to warrant scheme- and tool-independency. The data provided by the IFC file is analyzed. Using enrichment methods based on a multistage hierarchical decision system, non-existing values are added to the python instances. The multistage hierarchical decision system comprises five steps:

1. Search for default property sets or association sets (Export Tool dependent)
2. Use predefined functions to calculate required values from existing values
3. Use statistical data enrichment by predefined templates (JSON format)
4. Ask for user input (combined user query at the end of runtime if possible)
5. Use default values (if useful)

Thermal zones are generated based on IfcSpaces and linked to the corresponding building elements and space boundaries.

Based on the enriched data, simulation tool-specific preprocessing is executed. The building elements are mapped to the corresponding parameters of the simulation tools.

For building performance simulations in TEASER, a multiroom Modelica model is generated with TEASER mako templates. For the simulation in EnergyPlus, the geometry of each IfcRelSpaceBoundary is generated using OpenCascade and exported to EnergyPlus using the geomeppy library (MIT License). If no space boundaries are provided in the IFC data, a space boundary generation algorithm is applied.

Task 3: Application and Dissemination

WP 3.1 Application

In this work package a District Energy Simulation Test (DESTEST) is under development. The aim is to provide a means to validate models of urban energy systems or subsystems and to define district energy cases for testing in different simulation environments. The work has been split up in two groups that work interactively: (1) the building modeling group focusses on the selection and modeling of the buildings in the district, and (2) the network modeling group investigates the sizing and operation of the energy network. The developments are actively ongoing, with regular coordination and subgroup meetings.

The main activity was focused on the continued development of the DESTEST

Several common exercises with increasing complexity were initiated. In a first common exercise 16 identical residential buildings were described. The increased complexity includes the definition of different occupant types, the definition of residential buildings with other thermal properties and the definition of an office building. The load of buildings served as an input to the network modeling group who made network with different layouts and number of buildings. The activities also were documented in text and CityGML format to allow future participants to easily execute the past exercises and to already prepare document writing. Activities also included the development of procedures to compare the results generated by the different participants.

Publications:

Saelens, D., De Jaeger, I., Bünning, F., Mans, M., Vandermeulen, A., van der Heijde, B., Garreau, E., Maccarini, A., Rønneseth, Ø., Sartori, I., Helsen, L. (2019). Towards a DESTEST: a District Energy Simulation Test Developed in IBPSA Project 1. In: BS'2019, (1-8). Presented at the Building Simulation Conference 2019, Rome, 02 Sep 2019-04 Sep 2019.

Abstracts about this work package were submitted to BS2021 Conference.

WP 3.2 Dissemination

The goal of this work package is to demonstrate capabilities enabled by the use of Modelica for building and district energy systems. This task is accomplished by collecting a number of case studies and describing them through a unified template that facilitates a systematic comparison and illustrates key findings from different applications.

So far, 11 case studies have been collected, ranging from hydronic heating loops and cooling systems in data centers to district heating networks and multi-infrastructure smart community systems. All case studies have been developed using models from open-source Modelica libraries.

The information gathered through the templates have been uploaded to the project website at https://ibpsa.github.io/project1/applications. Here, for each case study, it is possible to find information such as the objective of the simulation study, the energy system diagram, and other modeling and simulation details such as thermal zoning and computational time.

4 Unforseen events

None.

5 Issues requiring attention of the Board

None.