Demo Abstract: MLE+: Design and Deployment Integration for Energy-Efficient Building Controls

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Abstract

While building simulation software tools are excellent at carrying out accurate and realistic building simulations they only provide very basic control methods. On the other hand, control engineers and researchers have explored advanced control strategies for energy-efficient operation of a building, but more often than not, such methods are based on simplified physical models instead. We present MLE+, a tool for energy-efficient building automation design, co-simulation and analysis. The tool leverages the high-fidelity plant simulation capabilities of building modeling software, EnergyPlus, and the scientific computation and design capabilities of Matlab/Simulink for controller design. MLE+ facilitates integrated building simulation and controller formulation with integrated support for system identification, control design, optimization, simulation analysis and communication between software applications and building equipment. In this demo, we will show how MLE+ can be used for systematic design of controllers for energy-efficient building model in EnergyPlus. We will also show the capability of MLE+ to control Heating Ventilation and Air Conditioning (HVAC) devices in buildings through the BACnet protocol.

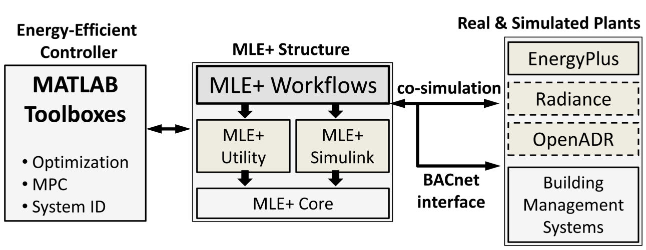

Figure 1. MLE+ interfaces control systems toolboxes with building models and systems

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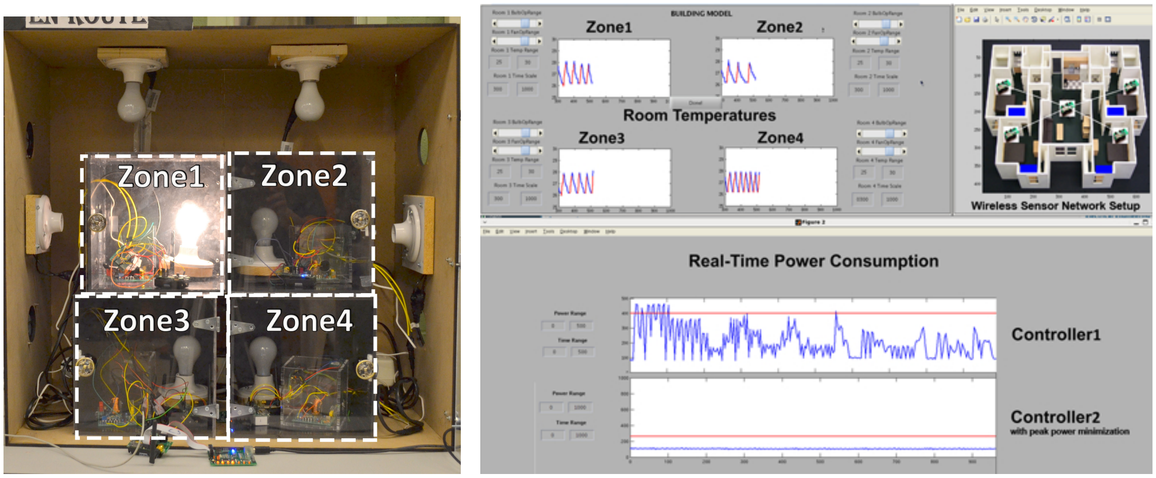
1 Introduction

MLE+ is intended to be used as a tool for building energy research and development by researchers who are familiar with Matlab and want to use realistic building simulation capability of building energy simulation software like EnergyPlus [1]. MLE+ allows integrated building simulation and controller formulation with support for system identification, control design, optimization, simulation analysis and communication between building simulation software as well as building equipment.

EnergyPlus is one of the most robust building energy analysis and thermal load simulation tools available today. It allows simultaneous simulation of loads, systems, and plant and therefore permits quick assessment of building performance. However, EnergyPlus lacks the capability to directly interface with scientific computation and simulation software such as Matlab [2] and Simulink. Therefore, it is difficult to implement and simulate advanced control feedback strategies such as Model Predictive Control (MPC), where an optimal control signal is repeatedly computed based on the current state of the controlled plant. It requires considerable effort and time for a control expert to obtain working knowledge of EnergyPlus, become familiar with its elaborateness and use it for implementing advanced control algorithms.

MLE+ is an open-source Matlab/Simulink toolbox for building energy research and development (Fig 1). It has co-simulation capabilities with EnergyPlus from Matlab and provides a BACnet interface to real building equipment. The next are its main features:

1. **Simulation configuration**: The MLE+ front-end streamlines the configuration process of linking the building model and the controls in the co-simulation. This reduces setup time and configuration problems.
2. **Controller design**: MLE+ provides a control development work-flow and graphical front-ends (Fig. 3) for designing advanced control strategies, in which the building simulation is carried out by EnergyPlus while the controllers are implemented in Matlab or Simulink.
3. **Simulation-based optimization**: MLE+ can be used to find optimal parameters or control sequences for building system simulations in EnergyPlus.
4. **Data analysis**: Co-simulation results from EnergyPlus can be aggregated, analyzed and visualized in MLE+.



(a) Test bed with 4 zones (b) Energy dashboard showing zone temperatures and power

Figure 2. Building test-bed with BACnet connectivity to MLE+

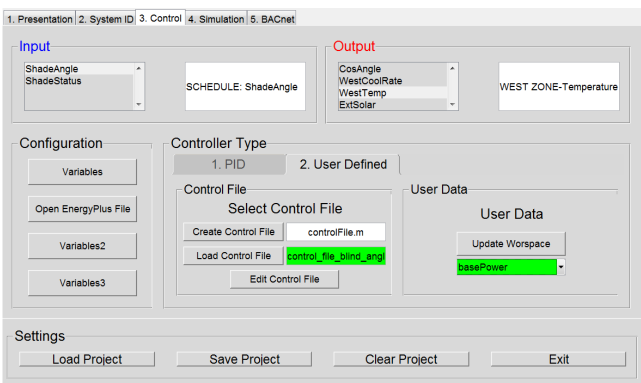


Figure 3. MLE+ tool interface

5. **Building Management System Interface**: MLE+ provides a BACnet interface to develop and implement control methods for real building equipment.
6. **Matlab environment**: MLE+ allows complete access to the Matlab environment and toolboxes such as Global Optimization Toolbox, System Identification Toolbox and Model Predictive Control Toolbox.

We now describe two case studies which demonstrate the aforementioned capabilities of MLE+ in designing and deploying energy-efficient control schemes for buildings.

2 Demo I: Energy-Efficient Controller Design

The objective of this case is to implement energy-efficient control algorithms for radiant heating systems and to show the potential and ease of use of MLE+ in implementing and evaluating such algorithms. A single floor, L-shaped building divided into three interior zones is used as the plant model. In the demo, we will follow the next steps in MLE+:

- Configuration of the co-simulation environment,
- System identification of the EnergyPlus model,
- Design of the energy-efficient controller using the identified model,
- Co-simulation with EnergyPlus using the energy-efficient controller
- Evaluation and comparison of different control strategies for the same building model
- Visualizing and analyzing co-simulation results within Matlab.

3 Demo II: BACnet capability in MLE+

For the second case study, MLE+ is interfaced with a test-bed that simulates both the dynamics of a building and the behavior of BACnet devices.

The test-bed consists of a building with four zones (Fig 2(a)) with independent heating and cooling elements that regulate its temperature. Sensor nodes monitor the temperature and energy levels in different zones of the building. An energy dashboard, shown in Fig.2(b), displays the current temperature of each zone and the overall power consumption. The test-bed is isolated from the surroundings by an outer box, which acts as the outside environment for the building. Fig. 2(b) shows that the temperature dynamics of each zone in the test-bed is similar to the dynamics of a real building.

Each zone of the building test-bed acts as a single BACnet device with a write and a read object. MLE+ interacts with them according to the designed controller. This controller, implemented in Matlab, periodically reads the temperature from each zone and switches the heating elements ON and OFF such that the temperature stays in a comfort range.

This is a simple example but it paves the way for using MLE+ for modern energy-efficient control methods such as MPC. Fig 2(b) shows the performance of two controllers implemented for the test-bed with MLE+. *Controller 1* controls each zone independently of the other zones. This uncoordinated behavior among the zones results in peaks in the total power consumption of the building. *Controller 2* coordinates the zone controls such that the peak power consumption for the building is minimized.

4 References

[1] D.B. Crawley, L.K. Lawrie, C.O. Pedersen, and F.C. Winkelmann. Energy plus: energy simulation program. *ASHRAE journal*, 42(4):49–56, 2000.

[2] Inc MathWorks. *MATLAB: the language of technical computing. Desktop tools and development environment*. MathWorks, 2005.