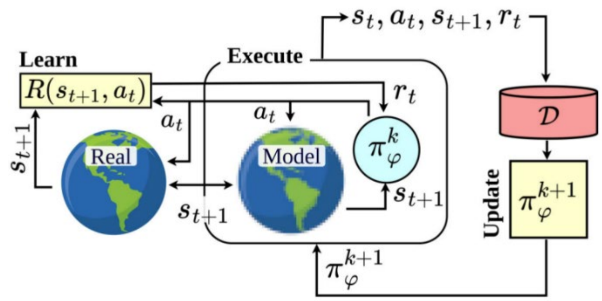
MS Thesis Project Opportunity

Carrier Corporation

Physics-Informed Reinforcement Learning for Building Energy Optimization

Problem Description:



Buildings account for 40% of energy consumption globally, and saving energy in building operation is therefore an important element of advancing towards a more sustainable energy landscape. Buildings are complex due to heterogeneous physical domains (thermodynamics, electrical, mechanical), of large scale (100s of sensors and actuators) and span a large range of time constants (from seconds to years). Commissioning and tuning of high-performance controls to reach energy-efficient operation is feasible but is time consuming and require skilled experts. Reinforcement learning is a promising approach since it has the potential of adaptively and autonomously optimize energy consumption during operation. However, RL is also known to require extensive data for learning and scaling to large systems is non-trivial. ***In this project, Physics-Informed Reinforcement Learning (PIRL) is explored as a method for building energy optimization***.

Project Description:

The use of PIRL methods to tune regulatory control loops in order to improve energy efficiency in buildings will be explored in this project. This will be done using dynamic models to represent the building dynamics, and to generate synthetic data for algorithm learning, and by use of selected PIRL algorithms. Particular attention will be given to selection physics priors to speed up learning and scalability of RL methods. The project will also study how RL can improve water side operation of a building cooling system, including turning equipment units (chillers) on and off and resetting water-side temperature set-points. Questions of interest for the thesis project are:

- How to select physics priors for PIRL methods in building systems?
- How much data is needed to train the algorithms with and without physics priors?
- How can the structure (architecture) of a building system be exploited to better scale up PIRL?

The project will also include to use and refine dynamic Modelica building models constructed from the open-source Buildings Library developed by Lawrence Berkeley National Laboratory, as well as regulatory control systems that are common in building system operation. Numerical experiments (Python, Julia, Jupyter notebooks) will be used to carry out the mathematical analysis to assess the scaling potential of PIRL.

A stretch goal is to understand and carry out Software in the Loop (SIL) methods using PRIL methodology with Carrier Automated Logic building control software.

The student(s) will work closely with Carrier engineers that are experts in chiller systems and chiller systems modeling.

Student profile:

Skilled students with interest in machine learning, automatic control, physics of energy equipment, optimization, and programming. Experience with thermofluid systems, Python programming, and numerical methods for optimal control will be beneficial.

Supporting team:

- Johan Åkesson (lead Carrier advisor and point of contact)
- Clas Jacobson (Carrier Senior Fellow Systems and Controls)
- Bo Bernhardsson (lead LTH point of contact)
- Liang Chang (Group Leader, Controls at Carrier)
- Michael Wetter (LBNL scientist — optimization, Modelica implementations and HVAC/R physics)

Carrier has recently opened an office in Lund and is interested in hiring students from successful MS Thesis projects.

References:

[Ban+23] C. Banerjee, K. Nguyen, C. Fookes and M. Raissi. A Survey on Physics Informed Reinforcement Learning: Review and Open Problems. Preprint. Sept. 2023.

[Wet+22] Michael Wetter, Paul Ehrlich, Antoine Gautier, Milica Grahovac, Philip Haves, Jianjun Hua, Anand Prakash, Dave Robin and Kun Zhang. ‘OpenBuildingControl: Digitizing the control delivery from building energy modeling to specification, implementation and formal verification’. In: Energy (2022).