Graduation Plan

Master of Science Architecture, Urbanism & Building Sciences

Graduation Plan: All tracks

Submit your Graduation Plan to the Board of Examiners (Examencommissie-BK@tudelft.nl), Mentors and Delegate of the Board of Examiners one week before P2 at the latest.

The graduation plan consists of at least the following data/segments:

Personal information	
Name	Sebastian Fischer Stripp
Student number	5623871

Studio		
Name / Theme	Building Technology	
Main mentor	Dr. Michela Turrin	Design Informatics
Second mentor	Dr. Regina M. J. Bokel	Building Physics
Argumentation of choice of the studio	I am interested in how AI can be used for social good and improving our lives. This intersects with my interest for sustainability in the built environment through the application of building physics. This topic of building operation control using AI allows me to explore and develop solutions to a real problem with a large, positive societal impact.	

Graduation project	
Title of the graduation project	Clim(AI)te Control
Goal	
Location:	The case study is in Wales, UK and is a timber-framed primary school. This case study will provide a testing ground for sensitivity analysis, calibration testing, as well as transferability testing.
The posed problem,	If we are to meet the 2050 climate targets we have to develop cheap and widely applicable solutions for the built environment as most buildings in 2050 already exist today. This thesis approaches buildings as batteries for thermal/chemical energy storage and takes advantage of the natural fluctuations in energy supply. The diurnal fluctuations in solar radiation can be taken advantage of to

	reduce our reliance on on-demand energy. In addition, as our electrical grids shift towards a broader mix of renewables with a naturally fluctuating output, our buildings and infrastructure should react correspondingly to alleviate the pressures on the grid and take better advantage of renewable sources. Using reinforcement learning to control our buildings operation with the aim of responding to weather forecasting, this thesis aims to develop an agent that can be used to reduce energy demand in buildings.
research questions and design assignment in which these result.	**How can Reinforcement Learning be used to decrease energy expenditure in buildings, while maintaining user comfort, through predictive modelling based on weather forecasts?** Sub-questions: • How can a simulated energy model, including HVAC control and natural climate systems, be simulated and calibrated for monthly, daily and hourly intervals? • How can a RL agent be trained to control the building operation system, while maintaining indoor comfort levels? • What is the performance of the agent compared to the baseline performance? • How can the agent be improved and how does building design and energy supply features influence the potential performance of the agent?
	[Design Assignment]

[This should be formulated in such a way that the graduation project can answer these questions. The definition of the problem has to be significant to a clearly defined area of research and design.]
The purpose of this thesis is to develop an RL agent that can operate a building better than existing rule-based controllers. The case study will be used to develop the agent as well as to test and validate its performance.

Upon successful completion, depending on time, further investigations may be undertaken looking at the boundary conditions, limitations, sensitivity analysis, dimensionality reduction, calibration testing, as well as transferability. Benchmarking on public benchmark buildings may also be carried out in a later stage if time permitting.

Process

Method description

Starting with a literature review to assess the current progress and methods in this field, the thesis will then move on to modelling the case study with the awareness of what previous researchers have accomplished.

The case-study will be modelled in a building simulation software and calibrated using data measured on-site. These simulations will then be used to develop, train and test the Reinforcement Learning agents as well as discover the key parameters of the building influencing their operation and saving potentials. This will be tested against the standard rule-based controller.

Doing this breaks down into the following steps (subject to change):

1. Simulating the energy performance of the building at hourly, daily, monthly and yearly intervals.

2. Simulating the automatic control systems of the building (HVAC systems).

3. Simulating the manually controlled climate systems (windows and natural ventilation).

4. Calibrating the simulations using measured data.

5. Training the DRL (AI) agent to control the building systems while maintaining the prescribed comfort level.

6. Testing DRL agent against baseline performances in simulation.

Minimal required to answer research question. The following is additional depth. Time permitting.
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7. Rebuilding of DRL agent to discover critical features and parameters of the model, sensitivity, dimensionality reduction, and calibration etc.

8. Determine potential improvement/changes to buildings that result in larger potential impact of predictive control, to assess which buildings have greater potential.

9. Determine scalability and wider applicability on other projects as well as required setup for implementation.

To support the development of the DRL models, courses from the TU Delft Computer Science department are being followed, as well as numerous online resources being consulted to learn essential techniques and programming libraries.

The following tools will be used (subject to change):
EnergyPlus, EnergyPlus API, IDF and/or OpenStudio, EMS
Python, PyTorch, + other common libraries (Numpy, Pandas etc.)
Grasshopper with Ladybug and Honeybee
OpenAI-Gym for DRL practice and learning

Literature and general practical preference

[The literature (theories or research data) and general practical experience/precedent you intend to consult.]

The following are some of the primary sources, however, more than 30 sources on innovative building and system control including Machine Learning have already been examined.

Meta-studies of RL and general building operation:

Han, M., May, R., Zhang, X., Wang, X., Pan, S., Yan, D., Jin, Y., & Xu, L. (2019). A review of reinforcement learning methodologies for controlling occupant comfort in buildings. Sustainable Cities and Society, 51, 101748. https://doi.org/10.1016/j.scs.2019.101748

Li, X., & Wen, J. (2014). Review of building energy modeling for control and operation. Renewable and Sustainable Energy Reviews, 37, 517–537. https://doi.org/10.1016/j.rser.2014.05.056

Vázquez-Canteli, J. R., & Nagy, Z. (2019). Reinforcement learning for demand response: A review of algorithms and modeling techniques. Applied Energy, 235, 1072–1089. https://doi.org/10.1016/j.apenergy.2018.11.002

Energy model Bayesian calibration:

Muehleisen, R. T., & Bergerson, J. (2016). Bayesian Calibration—What, Why And How. 10.

Reflection

1. What is the relation between your graduation (project) topic, the studio topic (if applicable), your master track (A,U,BT,LA,MBE), and your master programme (MSc AUBS)?
   The MSc AUBS is about the built environment in a very broad sense. Covering a range of scales from the urban, to the building and even down to the product

and material scale. In addition, it looks both at the history of the built environment as well as the future. The Building Technology track is primarily focused on the future – both on what is next, but also how to bring the present into the future. This thesis is situated at that intersection of examining existing buildings with the intent of improving them to meet our future demands considering the global climate crisis.

2. What is the relevance of your graduation work in the larger social, professional and scientific framework.
   The social impact of this could be enormous if applied to 1000's of buildings as it would help stabilize energy grids and save money for building operators and owners. While Reinforcement Learning has been applied to building control before, it has not been done in the way and with the combination of tools set out in this thesis. In addition, weather as an input parameter is not widely represented in the literature.