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	Charlotte Jeline Kat
Student number	5487528

Studio		
Name / Theme	Building Technology	
Main mentor	Michela Turrin	Design Informatics
Second mentor	Eleonora Brembilla	Climate Design
Argumentation of choice of the studio	I chose to combine the chairs Design Informatic and Climate Design within Building Technology as I believe that the design of comfortable and healthy buildings can be empowered by integrating computational tools to support the designers in making informed design decisions.	

Graduation project	
Title of the graduation project	Visual comfort l(AI)outs Interior layout parameters affecting daylight and view quality
Goal	
Location:	-
The posed problem,	The interior layout of apartments is made in the early design stage of an architectural project when the decisions can significantly impact the building's performance. The influence of daylight and view quality is essential to building performance since daylight affects people's health. Artificial intelligence could support performance-based decision-making for the interior zoning of buildings based on daylight and view. However, a machine learning method is missing to support designers based on early interior design decisions that affect daylight and view quality.
research questions and	This study aims to automatically generate apartment layouts with sufficient daylight and access to view of sky. To achieve the purpose of this study, this research addresses the following research question:

	How can a machine learning algorithm support designers based on early interior layout design parameters that affect daylight and view comfort in residential buildings? To answer the main research question, the following sub-questions will be answered: SRQ 1. How do daylight and view quality influence the different spaces of apartments? SRQ 2. What daylight and view quality requirements and parameters characterise different apartment room types? SRQ 2.1. What are the daylight requirements for the different rooms of an apartment? SRQ 3. How can a machine learning algorithm integrate daylight and view in an assessment tool to support the designer's interior zoning of apartments early in an architectural design? SRQ 3.1. Which machine learning algorithm is the best for combining two different domains? SRQ 3.2. How can a machine learning algorithm be a development assessment tool for predicting daylight and visual comfort SRQ 3.3. Which machine learning algorithm is most suitable for capturing relations and similarities between two different domains of different dwelling layouts?
Design assignment in which these results.	This thesis aims to assess the potential of artificial intelligence vision models to utilise deep learning algorithms to accelerate interior zoning design decisions. This research aims to develop a system that will display the building performance of various design possibilities to support designers in making more accurate design decisions. The main focus of this research is the intersection between two different building performances, namely, daylight and view quality. The study will prove if combining the two performances is possible with one machine learning method. The performances will be condensed for the sake of this research. This means that one indicator for daylight and one indicator of view quality will be used as a demonstrator. This method will support the designer by considering both factors in the same decision-making process; this corresponds to a real-world scenario in which a multicriteria assessment must find a balance between many domains. The outcome might need to be more reliable to say something about the quality of sufficient daylight and view of a particular space since the indicators need to be more concise. For the sake of this research, the reliability of the numeric results is less critical since the focus is on the method that allows for a combination of two different domains. However, if the combination

	proves successful, the method can be expanded in further steps. This is primarily a computational time issue and might result in layouts with reliable performance outcomes. Even though making performance-based judgments with only two indicators is uncommon, these demos are intended to show how the methodology works. The main goal is to run the dataset with the thought of combining these two distinct domains.

Process

Method description

In order to answer the research questions and address the main objectives of this thesis, this research follows a mixed-methods study. The methodology consists of three phases guiding the research: discovery, development, and evaluation.

1.5.1 Discovery phase

The discovery phase involves collecting and analysing relevant literature on the topic to provide a comprehensive understanding of the current state of the research. The discovery phase includes identifying key concepts, theories, and methodologies related to the research questions. The literature study considered various search, screening and selection methods for publications related to natural (day)light, view quality and AI. In this study, 6 keywords are selected, namely, natural (day)light, view quality, visual comfort, dwelling, layout optimisation, and machine learning (ML) algorithm. The keywords were searched in databases such as Google Scholar, Scopus, Science Direct and Web of Science. Titles and abstracts were screened to find relevant papers. The literature research consists of two main parts that will investigate existing research on the topic. The literature study has four parts to answer the sub-questions. The first part defines the influence of daylight and view quality on the interior layout of apartments. Secondly, a literature review on the requirements of daylight and view in residential buildings is done. The third part reviews ML methods to predict and validate daylight and view quality. Lastly, a literature review on ML methods to capture relations and similarities between two different domains is done. The review on AI will also ensure that getting more familiar with these tools and models. This review specifies the best ML tool and creates the basis for the tool development framework.

1.5.2 Development phase

The development phase involves the design and implementation of the research study, including developing a machine learning tool and data collection procedures. The first step is to define the features and labels used. Secondly is cleaning up the Swiss dataset to create a data frame. The data framework will be divided into two parts: the training and test samples. The knowledge from the discovery phase and the input and output of the data frame will define the proper machine learning algorithm that might alter slightly during the training process. When a machine learning algorithm is defined, the training samples train the machine learning tool, and the model should be able to predict the daylight performance and the view

quality of different rooms in an apartment. The machine learning algorithm will then be able to create residential layouts with sufficient daylight and view qualities.

1.5.3 Evaluation phase

The evaluation phase evaluates the machine learning tool to provide a detailed and objective assessment of the strengths and weaknesses of the program and identifies areas of improvement. The test samples will test the trained machine-learning tool, giving insight into the tool's loss function. The evaluation of the ML model will give insight into the interior parameters that affect daylight and view quality of residential layouts. Lastly, the final findings of the evaluation are reflected on and summarised in the report.

Literature and general practical preference

Daylight, view & layouts

The review on how daylight and view quality influence different spaces, will be mainly derived from Anderson, Ko et al., and Neufert et al. on this topic.

Anderson, S. R. (2003). Health and design [Texas Tech University]. http://hdl.handle.net/2346/50045

Ko, W. H., Kent, M. G., Schiavon, S., Levitt, B., & Betti, G. (2022). A Window View Quality Assessment Framework. LEUKOS, 18(3), 268–293. https://doi.org/10.1080/15502724.2021.1965889

Neufert, E., Neufert, P., & Kister, J. (2012). Architects' data (4th ed). Wiley-Blackwell.

Daylight and view requirements and basics

The basic terminology and requirements for residential buildings for daylight and view quality mainly comes from the following resources:

Boyce, P. R. (2003). Human Factors in Lighting (Second Edition). Taylor and Francis.

EN 17037 (NEN-EN 17037). (2022).

Mardaljevic, J., Andersen, M., Roy, N., & Christoffersen, J. (2011). Daylighting Metrics for Residential Buildings. Proceedings of the 27th Session of the Commission International de l'Eclairage, CIE 197:2011, 93–111.

Nabil, A., & Mardaljevic, J. (2005). Useful daylight illuminance: A new paradigm for assessing daylight in buildings. Lighting Research & Technology, 37(1), 41–57. https://doi.org/10.1191/1365782805li128oa

Pilechiha, P., Mahdavinejad, M., Pour Rahimian, F., Carnemolla, P., & Seyedzadeh, S. (2020). Multi-objective optimisation framework for designing office windows: Quality of view, daylight and energy efficiency. Applied Energy, 261, 114356. https://doi.org/10.1016/j.apenergy.2019.114356

Raynham, P., Boyce, P. R., & Fitzpatrick, J. (2012). The SLL code for lighting. Society of Light and Lighting.

Reinhart, C. (2014). Fundamentals designing with the sun (R. Stein, Ed.). Selbstverlag.

Tregenza, P., & Wilson, M. (2011). Daylighting: Architecture and lighting design. Routledge.

Machine learning, daylight and view quality

The review on the application of machine learning algorithms in combination with daylight and view quality mainly comes from the following references:

Ayoub, M. (2020). A review on machine learning algorithms to predict daylighting inside buildings. Solar Energy, 202, 249–275. https://doi.org/10.1016/j.solener.2020.03.104

Du, T., Jansen, S., Turrin, M., & Dobbelsteen, A. van den. (2021). Effect of space layouts on the energy performance of office buildings in three climates. Journal of Building Engineering, 39, 102198. https://doi.org/10.1016/j.jobe.2021.102198

He, Q., Li, Z., Gao, W., Chen, H., Wu, X., Cheng, X., & Lin, B. (2021). Predictive models for daylight performance of general floorplans based on CNN and GAN: A proof-of-concept study. Building and Environment, 206, 108346. https://doi.org/10.1016/j.buildenv.2021.108346

Le-Thanh, L., Nguyen-Thi-Viet, H., Lee, J., & Nguyen-Xuan, H. (2022). Machine learning-based real-time daylight analysis in buildings. Journal of Building Engineering, 52, 104374. https://doi.org/10.1016/j.jobe.2022.104374

Lin, C.-H., & Tsay, Y.-S. (2021). A metamodel based on intermediary features for daylight performance prediction of façade design. Building and Environment, 206, 108371. https://doi.org/10.1016/j.buildenv.2021.108371

Lorenz, C.-L., Packianather, M., Spaeth, A. B., & Bleil De Souza, C. (2018). Artificial Neural Network-Based Modelling for Daylight Evaluations. Proceedings of the 2018 Symposium on Simulation for Architecture and Urban Design (SimAUD 2018). 2018 Symposium on Simulation for Architecture and Urban Design, Delft, Netherlands. https://doi.org/10.22360/SimAUD.2018.SimAUD.002

Ngarambe, J., Adilkhanova, I., Uwiragiye, B., & Yun, G. Y. (2022). A review on the current usage of machine learning tools for daylighting design and control. Building and Environment, 223, 109507. https://doi.org/10.1016/j.buildenv.2022.109507

Nourkojouri, H., Shafavi, N. S., Tahsildoost, M., & Zomorodian, Z. S. (2021). Development of a Machine-Learning Framework for Overall Daylight and Visual Comfort Assessment in Early Design Stages. Journal of Daylighting, 8(2), 270–283. https://doi.org/10.15627/jd.2021.21

Radziszewski, K., & Waczynska, M. (2018). Machine Learning Algorithm-Based Tool and Digital Framework for Substituting Daylight Simulations in Early-Stage Architectural Design Evaluation. Proceedings of the 2018 Symposium on Simulation for Architecture and Urban Design (SimAUD 2018). 2018 Symposium on Simulation for Architecture and Urban Design, Delft, Netherlands. https://doi.org/10.22360/SimAUD.2018.SimAUD.001

Wu, A. N., Stouffs, R., & Biljecki, F. (2022). Generative Adversarial Networks in the built environment: A comprehensive review of the application of GANs across data types and scales. Building and Environment, 223, 109477. https://doi.org/10.1016/j.buildenv.2022.109477

Zou, Y., Zhan, Q., & Xiang, K. (2021). A comprehensive method for optimizing the design of a regular architectural space to improve building performance. Energy Reports, 7, 981–996. https://doi.org/10.1016/j.egyr.2021.01.097

A detailed list of the bibliography can be found in the references list of the P2 report.

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 Building Technology Master track is part of the Master Architecture, Urbanism and Building Sciences (MSc AUBS) and covers topics that cover the bridge between architectural design and engineering. The master tracks consist of five chairs that relate to different parts of the environment design field. Building Technology focuses on interdisciplinary problems that require innovative solutions.

This thesis, "visual comfort l(AI)outs", relates to two chairs within Building Technology. Firstly Design Informatics is involved in generating a machine learning tool to find the interior layout parameters that affect the daylight and view and to find the optimal layouts based on this. Secondly, Climate Design is integrated to create visually comfortable residential layouts. Combining these two fields allows for broadening the possibilities of optimising everyday design tasks through Artificial Intelligence. With this workflow, AI can contribute to efficiently assisting designers and engineers in the early decision-making stage of residential layout exploration.

2. What is the relevance of your graduation work in the larger social, professional and scientific framework.

Societal relevance

The ISO-15392 (2019) describes that standard sustainability involves three mutually interrelated aspects: environmental, economic, and social. This study directly or indirectly touches all three aspects. Improving the daylight quality of a room tackles the environmental aspect indirectly. Good daylight performance results in lower electricity demand, which increases the sustainability of a building. Facilitating designers with a tool tackles the economic aspect because the designers will have fewer repetitive tasks. Designers can focus on the more creative tasks of a design when they have fewer repetitive tasks.

Daylight can have a significant impact on the social well-being of residents. Adequate natural light increases the comfort of space and can improve mood, reduce stress, and promote overall health and productivity. Natural lighting and view to the exterior can also create a sense of connection to the outdoors and promote a sense of community within a building. Furthermore, a lack of natural lighting can make a space feel cramped and uninviting and contribute to feelings of isolation and depression. Architects must consider the social impact of daylight and view when designing apartment buildings, mainly since people spend most of their time indoors.

Scientific relevance

Creating a layout that complements the building's performance is demanding. This thesis focuses on combining daylight performance and view quality to optimise the performance of a residential layout. Understanding the possibilities of how machine learning can determine which interior layout design parameters affect the daylight and view comfort of residential buildings will provide valuable insight regarding the future development of the artificial intelligence field.